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THE TIROS VII METEOROLOGICAL SATELLITE SYSTEM

POST-LAUNCH EVALUATION REPORT

(NASA-CR-139068) THE TIROS 7 METEOROLOGICAL SATELLITE SYSTEM POST-LAUNCH EVALUATION REPORT (Radio Corp. of America) 165 p

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Prepared for the

GODDARD SPACE FLIGHT CENTER
NATIONAL AERONAUTICS
AND SPACE ADMINISTRATION
WASHINGTON, D.C.

By the

ASTRO-ELECTRONICS DIVISION
DEFENSE ELECTRONIC PRODUCTS
RADIO CORPORATION OF AMERICA
PRINCETON, NEW JERSEY

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PREFACE

This report contains the results of the Post-Launch Evaluation Program for the TIROS Meteorological Satellite System from the date of launch June 19, 1963, to the end of more than 30 months of successful operation in orbit, December 31, 1965. At the time of publication of this report, the satellite has continued to operate and is producing usable TV pictures. The evaluation program is being conducted for the Goddard Space Flight Center of the National Aeronautics and Space Administration (NASA) by the Astro-Electronics Division (AED) of the Radio Corporation of America, under contract No. NAS5-1335.

The TIROS VII satellite, more complex than any of the previous satellites in the TIROS series, was successfully launched from Cape Kennedy (then Cape Canaveral), Florida, on June 19, 1963, thus becoming the seventh consecutive success of the TIROS program in seven attempts. TIROS VII has, at the time of this writing, continued to perform with outstanding success for a period of more than two and one-half years, an unprecedented longevity for continuous, full operational capability in orbit for a meteorological satellite system.

In addition to the regular operational interrogations of TIROS VII, periodic interrogations of the satellite have been conducted by AED engineers to evaluate satellite performance and to investigate any changes in performance capability or in quality of performance. In addition, both theoretical analyses and engineering tests have been conducted to determine the most probable cause or causes of any changes in performance in the satellite subsystems. Such analyses and tests have been instrumental throughout the TIROS programs in the continued advancement and improved performance of satellite and ground station equipment, and in the refinement of ground station operations and data processing techniques.

Brief functional descriptions of the satellite subsystems and of the ground station equipment are included in this report. More detailed descriptions, including additional information concerning the design and technical development of the TIROS system, are contained or referenced in the TIROS VII final engineering report.

TIROS VII transmitted its 100,000th TV picture on orbit 9300 during a read-out at the Wallops Island CDA ground station on March 9, 1965. TIROS VII completed its 10,000th orbit on April 25. At the end of this reporting period, December 31, 1965, TIROS VII had completed over 13,700 orbits (927 days in orbit) with usable pictures still being received. As of April 25, 1966, the satellite continues to function satisfactorily. It has completed 34 months of operation in space, and in more than 15, 600 orbits, it has transmitted 123,000 television pictures. The operational life of this satellite has

greatly exceeded that of any preceding TIROS satellites. On April 25, 1966, the spin rate had decayed to 6.26 rpm from the last spin-up rocket firing on March 31, 1965, which increased the spin rate from 8.07 rpm to 11.20 rpm. The satellite's attitude is still stable. Despite the operational status of this satellite, the use of TIROS VII is strictly on a standby basis because of the successful launch of ESSA-1 on February 1966.

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I. INTRODUCTION

TIROS VII was successfully launched from Cape Canaveral, Florida, on June 19, 1963, at 09:50 01Z (04:50 01 EST) and injected into its planned orbit. The orbit is nearly circular, having an apogee at launch of 403.3 statute miles, a perigee of 385.9 statute miles, and a calculated eccentricity of 0.0020. It is inclined to the earth's equator at an angle of 58.2 degrees and the anomalistic period is 97.4 minutes. The normal point of the satellite's spin axis on the initial orbit was 39.8 degrees north latitude and 55.2 degrees east longitude (113.4 degrees right ascension). The successful performance of the satellite was demonstrated during the earliest orbits, making TIROS VII the seventh consecutive satellite in the TIROS program to achieve successful orbital performance in seven attempts.

The primary mission of the TIROS VII satellite was to provide increased weather observation during the 1963 hurricane season. The launching of TIROS VII was timed so that the satellite could be programmed to share two-hemisphere weather observations with the orbiting TIROS VI satellite, which had been launched approximately nine months earlier. The two satellites provided early detection and continued observation of many major hurricanes and typhoons that developed during the 1963 season. Many of the storms detected in their early stages were continuously monitored as they developed into severe disturbances.

TIROS VII is the first TIROS satellite to complete more than 24 months of operation with all major subsystems fully active and providing good performance. As of December 31, 1965, the operational life of TIROS VII has far exceeded that of any previous TIROS satellite. After more than 30 months in orbit, the camera No. 1 TV subsystem is functioning normally and is returning usable TV pictures. Camera No. 2 stopped sending usable pictures on October 15, 1965, after 28 months of operation in orbit. (However, it recovered and started sending usable data on orbit 14,144 on January 31, 1966). IR data and telemetry data of good quality was received by the TIROS ground complex for 18 months, until June 1965.

The TIROS VII satellite carries two one-half inch television cameras, each equipped with a wide-angle optical system. Each camera system is controlled individually by commands from the CDA (Command and Data Acquisition) ground stations and can be commanded to take and to simultaneously transmit TV pictures while in contact with a ground station (direct mode), or can be programmed to take pictures over remote areas of interest and record the picture data on magnetic tape recorders (remote mode). When in communication contact with a ground station, the satellite can be commanded to play back and transmit the recorded TV data to the ground complex.

In addition to the television systems, the satellite carries instrumentation and electronics for telemetry and beacon transmission, for the NASA/GSFC and University of Wisconsin infrared experiments, the University of Michigan electron temperature probe (ETP) experiment, for command address capability, for dynamics control, and for attitude control and determination. A solar-conversion array and storage batteries supply the power requirements of the satellite.

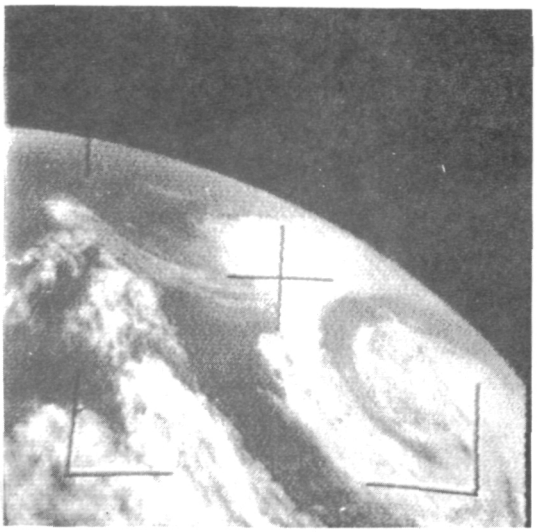
During the period of this report (from June 19, 1963 to December 31, 1965) TIROS VII provided 122,328 television pictures of the earth and its cloud cover. The consistently high quality of the pictures taken by TIROS VII is attested to by the high percentage of the pictures that were useful for meteorological analysis. Of the total of 122,328 pictures, 112,689 or 92.1 per cent were meteorologically useful. From these pictures, 3,683 nephanalyses were prepared and 630 storm bulletins and advisories were transmitted to weather stations throughout the world.

II. EVALUATION SUMMARY

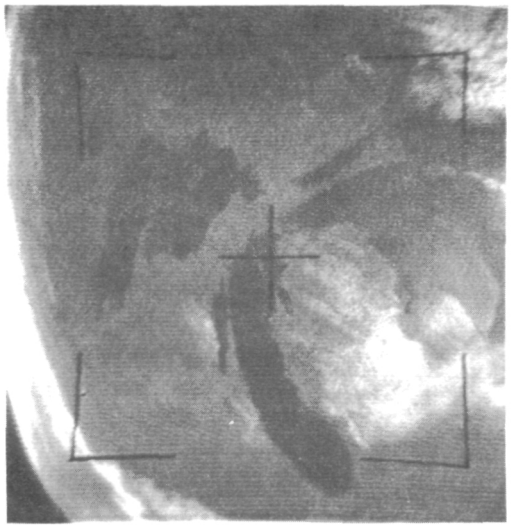
TIROS VII is the seventh consecutive successful TIROS satellite. It is the first TIROS satellite to complete more than 2 years of operation in orbit with all systems in full operation. On October 15, 1965, camera No. 2 temporarily stopped sending usable pictures after 28 months in orbit; however, it again started to send usable pictures (orbit 14,144) on January 31, 1966. (The quality of Camera No. 2 pictures remained good on an intermittent basis through April 25, 1966.) Camera No. 1 continues to send pictures of fair to good quality. A comparison of early orbit pictures and later orbit pictures taken by TIROS VII may be made by comparing the representative pictures shown in Figures II-1 and II-2, respectively.

Following the launch of TIROS VII, satellite separation from the third-stage rocket (at 21 minutes and 12 seconds after lift-off) and spin-down from the injection spin rate of 128 rpm to the operational spin rate of 8.3 (at 25 minutes and 44 seconds after lift-off) occurred on schedule. Separation was observed at 05:11.13 EST, the precession dampers were encaged successfully, and de-spin was observed at 05:15.45 EST by the Winkfield, England, station of the Minitrack network; de-spin was confirmed by the Pacific Missile Range (PMR) Command and Data Acquisition (CDA) station at San Nicolas Island, California. The San Nicolas CDA station made the initial interrogation of the TIROS VII satellite on the first orbit (001) and all subsystems responded normally to the initial commands. The Wallops Island, Virginia, station also interrogated TIROS VII on the first orbit with good results. During orbits 002 through 006, the satellite was commanded from both the San Nicolas and the Wallops Island stations. Some loss of playback transmission from camera system No. 1 was experienced; however, pictures taken in both modes of camera operation were of good to excellent quality. Figure II-1 was representative of early orbit pictures returned by TIROS VII.

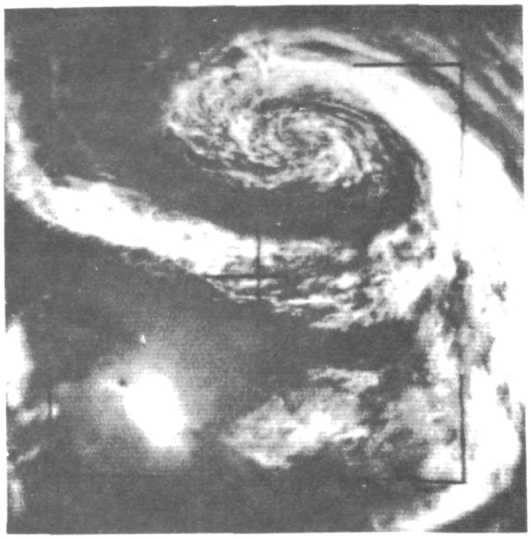
All major subsystems continued functioning normally throughout 28 months of operation in orbit, at which time camera No. 2 stopped sending usable pictures. However, camera No. 2 continues to perform satisfactorily and by December 31, 1965, the two camera systems had returned a total of 122,328 pictures, of which 112,689 (92.1 per cent) were useful for meteorological analysis. The picture quality from both systems was very high and degraded very slightly over this period. Only infrequent and random picture anomalies were observed and none showed evidence of any malfunction in the cameras, tape recorders, or transmitters. Until camera No. 2 becoming intermittent, decentering of camera No. 1 was the most severe deviation encountered and this never exceeded 8.8 per cent from normal and never prevented the pictures from being meteorologically useful. Some frames of the recorded pictures from the later orbits contained tape dropouts. However, except in rare instances, these dropouts did not detract from the usefulness of the pictures on which they appeared. The TV transmitters operated normally providing strong TV data signals to the ground stations throughout the 30-month evaluation period ending December 31, 1965.



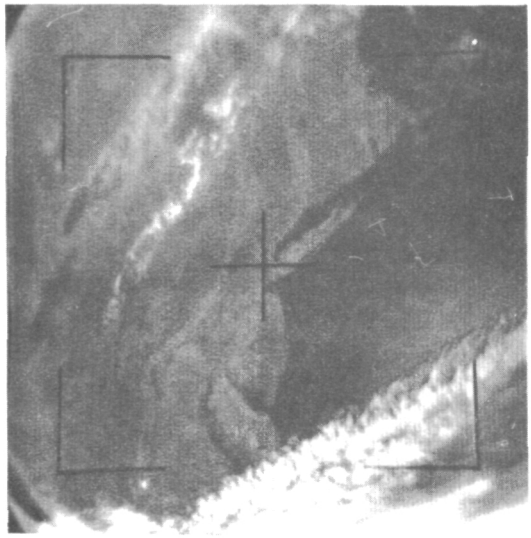
a. Circulation Center over Hudson Bay Area; Orbit 001, Camera 2, Direct



b. Great Lakes Region; Orbit 034, Camera 2, Direct

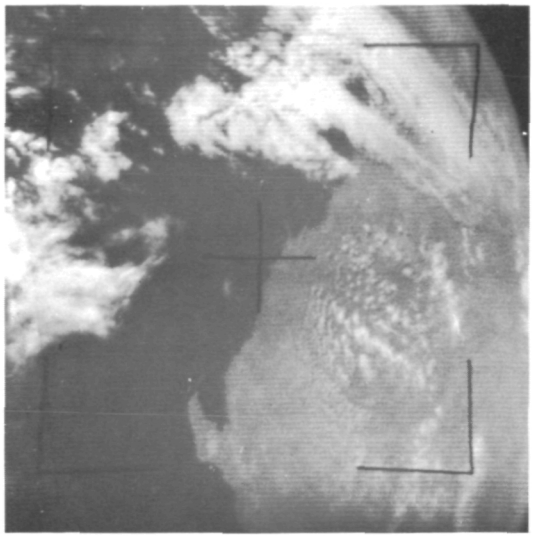


c. Vortex over Atlantic Ocean; Orbit 061, Camera 1, Remote

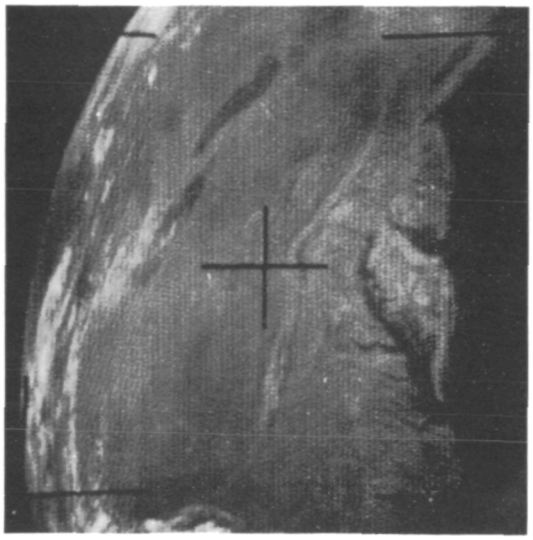


d. Northeastern Coastline of United States; Orbit 063, Camera 1, Direct

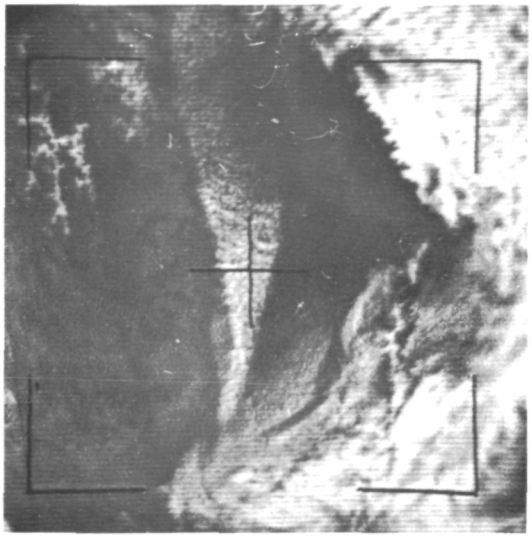
Figure II-1. Early Orbit Pictures



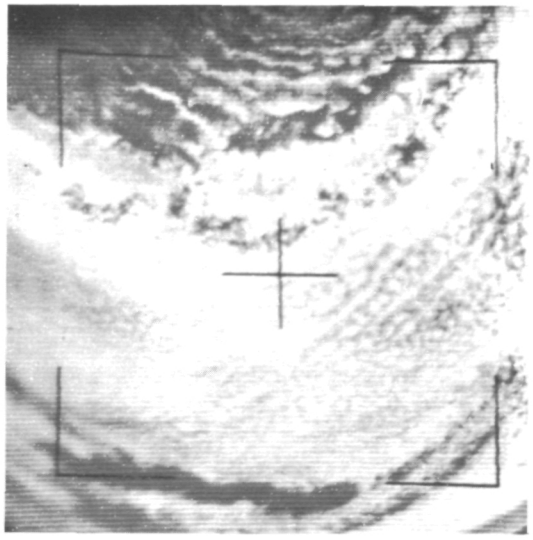
a. West Coast of Australia, Orbit 10672



b. East Coast of U.S. - North Carolina, Delaware, Maryland, and New Jersey



c. Clouds over Sea of Japan, Luzon Visible on Right Side of Picture, Orbit 13241



d. Clouds in Pacific Ocean Off Baja, California, Orbit 13253

Figure II-2. Later-Orbit TIROS VII TV Pictures

No malfunctions occurred in the satellite portion of the instrumentation control subsystem; however, there was evidence of reduced performance in the camera clock command control circuits. To a great extent, this problem was alleviated by improving the performance of the command equipment in the ground stations and by altering the format of the clock command transmissions. It was demonstrated by programming tests that no deficiencies existed in command sensitivity of the satellite or in the satellite command antenna pattern.

The performance of the NASA infrared subsystem, the University of Wisconsin omnidirectional infrared experiment, and the University of Michigan electron temperature probe (ETP) will be covered in a separate NASA document. This equipment produced large quantities of useful data. Several problems were encountered, including the disabling of the University of Wisconsin experiment by a malfunction of the IR telemetry switch, located in the IR package, a variation from normal in the playback time of the IR tape recorder, and a capacitor problem in the electron temperature probe lead.

The beacon transmitters of the telemetry and tracking subsystem provided strong signals for satellite tracking, performing continuously without malfunction. The telemetry data was consistent and provided good correlation accuracy. The 1-year timers, which were to have turned off the beacons at the end of 12 months in orbit, failed to operate, and it is believed that the self-contained batteries provided for these units failed.

The satellite dynamics control devices performed satisfactorily with the exception of the first two firings of the spin-up rockets which produced spin increases of approximately half the nominal value. The cause of this problem was not definitely established. However, subsequent firings of spin-up rockets did produce normal results. The normal condition of the last set of spin-up rockets despite 2-year storage was demonstrated in a group of special tests under space environment conditions. The results of these tests are reported in Appendix A of this document.

The despin (Yo-Yo) mechanism and the nutation damping (TEAM) mechanism performed normally. The performance of the magnetic attitude control (MAC) system and the predictive accuracy of the attitude control program were highly satisfactory. Except in a few instances in which the accuracy of the definitive attitude data was questionable, very good agreement existed between the predicted and observed satellite attitude data.

The satellite and ground station antenna patterns were, from all evidence, normal in every respect. The pattern of the satellite command antenna was determined in special tests, in connection with the clock-setting problem, and found to be normal.

The power supply subsystem performed normally and without malfunction throughout the evaluation period. The energy available exceeded the energy used on all but three days when, for a brief period in each case, the energy used slightly exceeded the energy available. In each case the energy balance was quickly restored by proper program planning.

Satellite thermal response was normal throughout the 30-month period. Average component temperatures remained between 0 and +35° C, well within the specified limits, and, except for brief periods, remained within the limits required for good performance of the solar array.

The reference indicator subsystem returned satisfactory sun angle and horizon data. No anomalies were encountered in either subsystem.

TIROS VII ground operations were conducted in a satisfactory manner. Launch preparations at the launch site and at the ground stations were performed efficiently.

In general, the CDA stations performed their assigned interrogations with a minimum of difficulties, despite the relatively heavy programming loads that existed while both TIROS VI and TIROS VII were operational. The quality of photographic negatives was, in general, high and consistent.

III. METEOROLOGICAL DATA COLLECTION

During the first operational day, TIROS VII was interrogated on 6 orbits (the satellite was not interrogated on orbit 3 because of the low satellite elevation angle above the horizon) and returned 208 TV pictures. From these, 10 nephanalyses were prepared. A well-developed vortex was observed over northern Quebec in Canada, frontal zones were photographed over the western United States, and ice and snow were observed over eastern Canada and southern Greenland. An Intertropical Convergence (ITC)* zone was observed over Africa, approximately 2 degrees north of the equator. Many land masses were identified in the pictures taken during this period, including Spain; Africa; Greenland; the Canadian Rockies; Trinidad; Goiania, Brazil; Barbados; the Leeward Islands; Baja, California; and the Guadeloupe Islands.

During the remainder of June 1963 (the first 11 days of operation), TIROS VII continued to provide remote and direct TV pictures of good to excellent quality. On June 23, 1963 (orbits 103 through 109), the programming for TIROS VII was planned to provide for recording IR data to be utilized in correlation studies with data obtained from radiometers on a balloon flight launched from Sioux Falls, South Dakota. During June 1963, TIROS VII returned a total of 3112 pictures to the ground complex. Of this total, 83 percent (2584) were meteorologically useful and provided 107 nephanalyses. Several storm vortices were detected over the northern part of the Pacific Ocean as well as Tropical Storm Trix which was located just north of the Philippine Islands.

Observations of typhoons, tropical storms, tropical depressions and hurricanes were made throughout July and August. A photograph of a broad frontal band located 600 miles southeast of Madagascar, taken on July 27 (orbit 562), is shown in Figure III-1. Among the storms observed were Tropical Storm (later Hurricane) Beulah, Tropical Storm Elaine, Typhoons Bess (Figure III-2), Carmen, and Della, and Hurricane Arlene. TIROS VII continuously monitored the northward progress of Typhoon Bess from approximately 375 miles northwest of Guam Island on August 2 until it crossed the southern tip of Japan on August 11, 1963. Hurricane Arlene was detected approximately 800 miles northeast of Trindad on August 3 and tracked as it passed within approximately 125 miles east of the Leeward Islands on August 5 and continued on a northwesterly course to a point approximately 900 miles north of Hispaniola. Hurricane Arlene then veered to the northeast and was last observed on August 10, approximately 600 miles northeast of Bermuda. Typhoon Carmen was first detected 500 miles east of the Philippine

*An ITC is a convergence of the northeast and southeast trade winds near the equator and is characterized by a long narrow strip of high clouds accompanied by showers and tropical disturbances.

Islands on August 9 and was tracked as it passed over Luzon on August 13 and continued on an easterly course. Observations of Carmen between August 15 and August 18, showed that it remained stationary at a position 100 miles east of Hainan Island off the southeast coast of China.

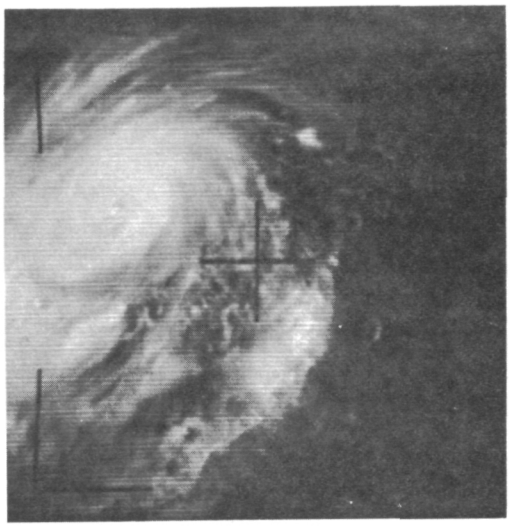


Figure III-1. Broad Frontal Band Southeast of Madagascar; Orbit 562, Camera 1, Remote

Figure III-2. Typhoon Bess at 20 N, 137 E; Orbit 678, Camera 2, Remote

In the last four months of 1963, TIROS VII observed Typhoons Faye, Gloria, Judy, Lola, Ora, and Susan; Tropical Storms Jennifer, Ester, and Helena; Tropical Cyclone Amanda; and Hurricanes Cindy, Edith, Mona, and Ginny. On September 8, a sandstorm was observed over western Africa. Hurricane Cindy was tracked from approximately 30 miles east of Galveston, Texas, on September 16, to southeast Texas on September 17. Hurricane Edith was detected approximately 480 miles east of Venezuela on September 24 and tracked for four consecutive days to a position over Hispaniola.

Breaks in the ice field along the coast of Antarctica were clearly visible on October 6. Hurricane Ginny was detected approximately 360 miles east of South Carolina on October 21 traveling in a southwesterly path. Ginny was tracked to a position approximately 130 miles east of Florida at a latitude of 28.7 degrees north where her course veered to the northeast toward South Carolina. Approximately 80 miles from the coast of South Carolina, on October 25, Hurricane Ginny turned northeast, and on October 27, passed a point approximately 360 miles east of South Carolina, the point where it had been first detected. From this point, Ginny turned north-northeast and, on October 28, was observed approximately 420 miles east of North Carolina.

During the first half of 1964, TIROS VII continued to provide good to excellent pictures. Examples are the picture of the California coast, taken by camera No. 1 in the direct

mode (Figure III-3a) on February 3, 1964 (orbit 3392), and the picture of snow-covered Kamchatka peninsula, taken by camera No. 2 in the remote mode (Figure III-3b) on April 6, 1964 (orbit 4326). In April, Tropical Cyclone Hazel was observed. Tropical Storms Jessie and Viola were observed in March. A broad storm vortex observed off the coast of New Zealand on March 3 (orbit 3810) is shown in Figure III-4. On March 28, TIROS VII provided coverage of the area of Alaska in which the major earthquake of that date occurred. A picture of this area taken several days later (April 3) is shown in Figure III-5.

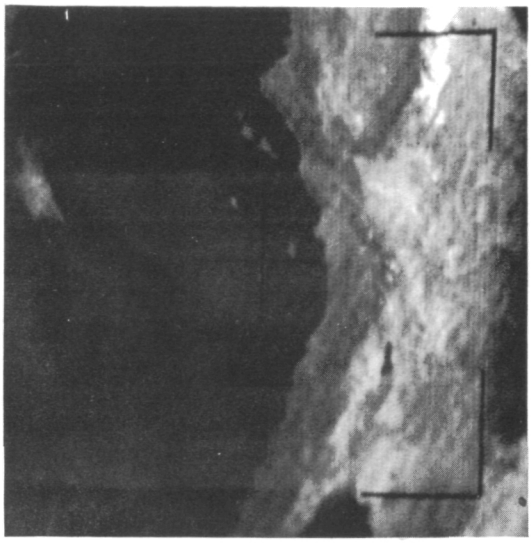
From July 1 until December 19, 1964, TIROS VII provided observations of hurricanes and tropical storms of the 1964 season. During this period, TIROS VII observed Tropical Storms Prudence, Marie (later Typhoon), Nancy, Ruby (later Typhoon), Ethel (later Hurricane), Tillie, Florence, and Hilda (later Hurricane, Typhoons Winnie, Betty, Kathy, Sally, Tilda, Hope, Kate, and Louise, and Hurricane Odessa, Cleo (later Tropical Storm), Dora (later Tropical Storm), and Gladys. A group of pictures of tropical storms and typhoons taken by TIROS VII during 1964 is presented in Figure III-6. A group of 1964 hurricane pictures is shown in Figure III-7. An unusual photograph of Typhoons Kathy and Marie, joined by a long spiral cloud, was taken during orbit 6296 and is shown in Figure III-8. An example of the resolution capability of the TIROS VII cameras after 11 months in orbit is shown in Figure III-9. The bright patch above and to the right of the center reticle mark is White Sands National Monument. A group of TIROS VII pictures from the second half of 1964, illustrating the resolution capabilities of both cameras after more than a year in orbit, is shown in Figures III-10 and III-11.

During January 1965, TIROS VII was programmed on a limited basis so that the CDA ground stations could prepare for the TIROS IX launching. Despite this reduced programming, TIROS VII photographed Tropical Storm (later Typhoon) Patsy and Tropical Storm Ruth during January. Tropical Storm Patsy was located 160 miles east of the Philippine Islands on January 19. By January 21, Patsy had intensified into a typhoon and was photographed 170 miles east of the Philippine Islands. Tropical Storm Ruth was photographed in the vicinity of the Mariana Islands on January 22. Between March 19 and 23, pictures from TIROS VII were used to provide supporting weather predictions for the Project Gemini flight.

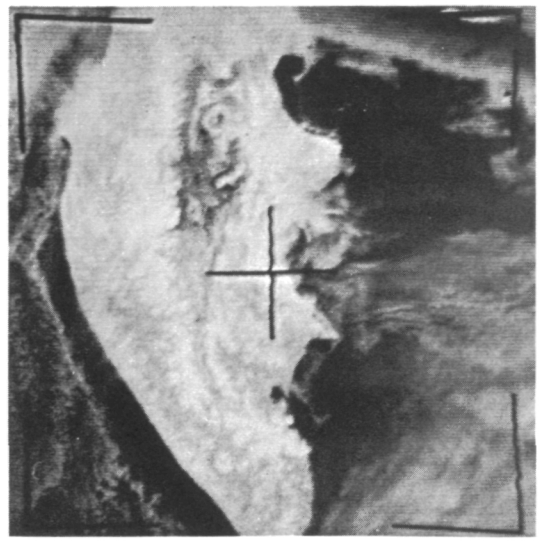
During June 1965, TIROS VII together with TIROS VIII and IX observed and tracked Typhoons Babe, Carla, and Dinah; and Tropical Storms Victoria, Wallie, Ava, Bernice and Emma. In August, TIROS VII observed Typhoon Mary.

During September 1965, TIROS VII observed and tracked the following storms on the dates indicated:

Date	Storm
9/8	Hurricane Betsy
9/12	Typhoon Trix
9/13	Typhoon Trix



a. *Coast of California and Channel Islands; Orbit 3392, Camera 1, Direct*



b. *Snow-Covered Kamchatka; Orbit 4326, Camera 2, Remote*

Figure III-3. TV Pictures Taken During First Half of 1964

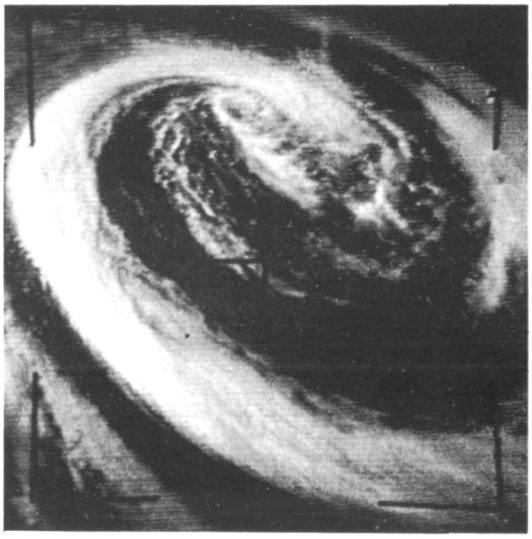


Figure III-4. Storm Vortex Near New Zealand Coast; Orbit 3810, Camera 2, Remote

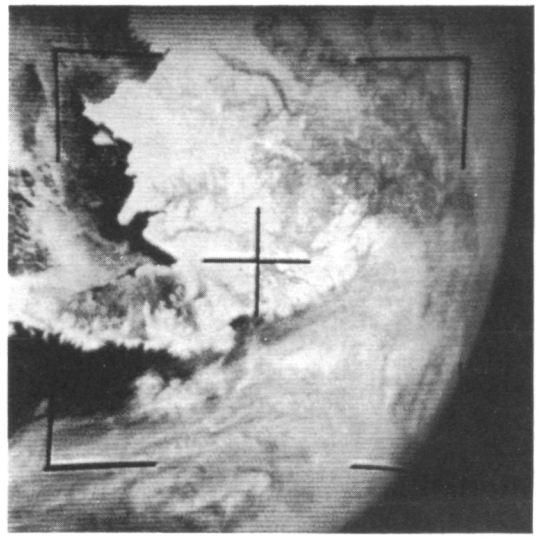
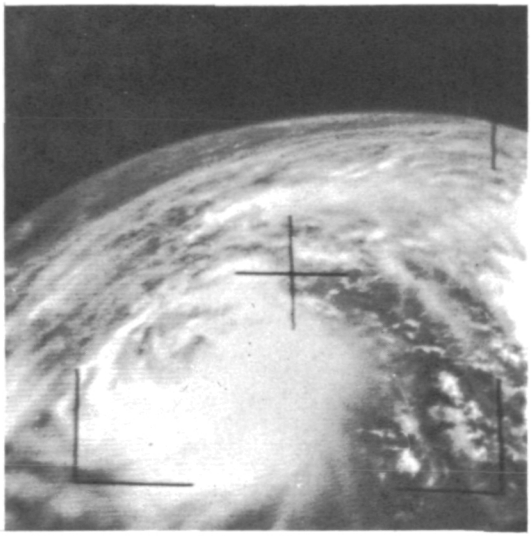
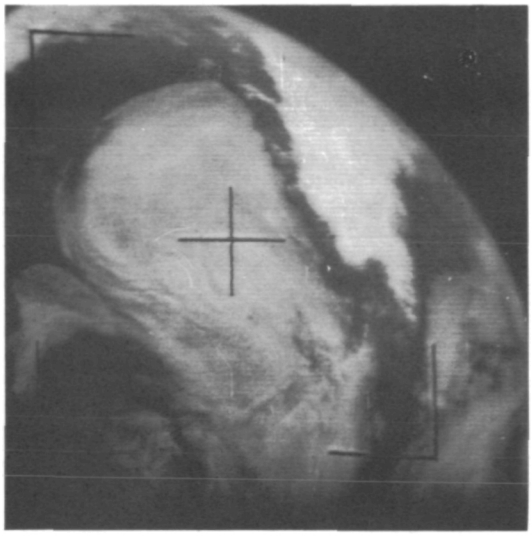


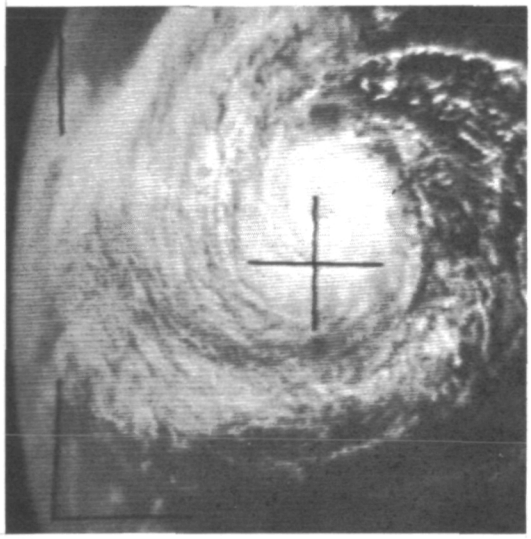
Figure III-5. Alaska Earthquake Area, Orbit 4266, Camera 2, Direct



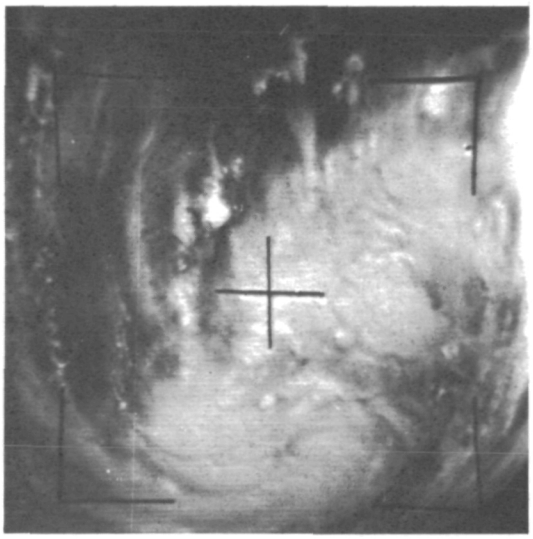
a. *Typhoon Kathy; Orbit 6281, Camera 1, Remote*



b. *Cloud System near Greenland; Orbit 6597, Camera 1, Remote*

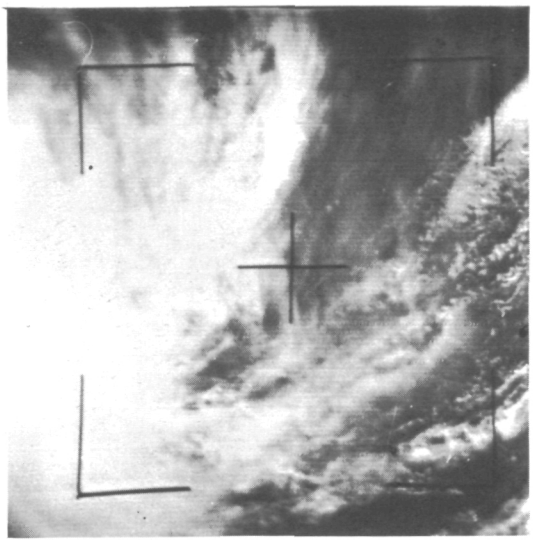


c. *Unnamed Tropical Storm South of California; Orbit 6923, Camera 2, Remote*

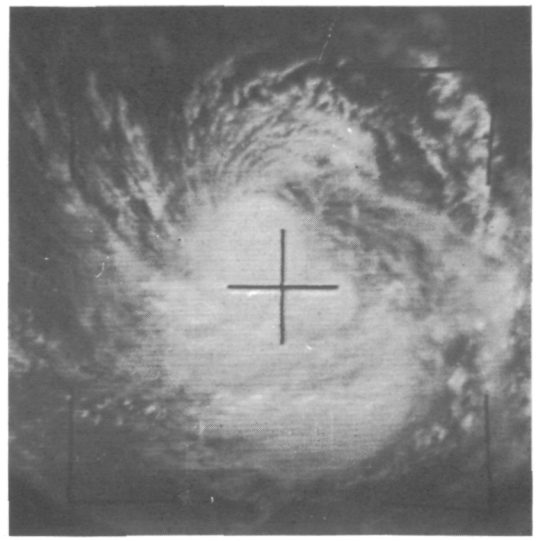


d. *Typhoon Kate; Orbit 7609, Camera 2, Remote*

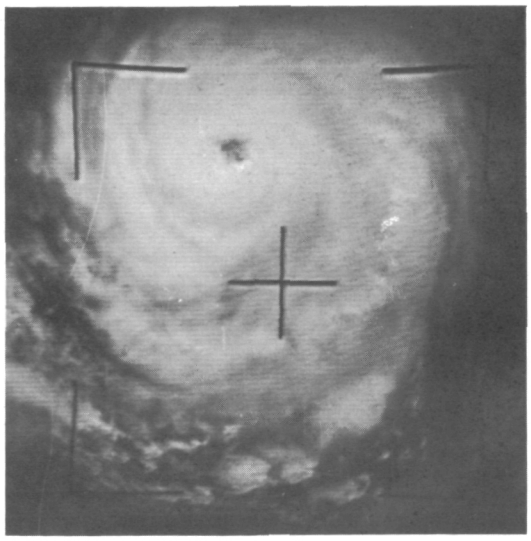
Figure III-6. Tropical Storms and Typhoons Photographed by TIROS VII During 1964



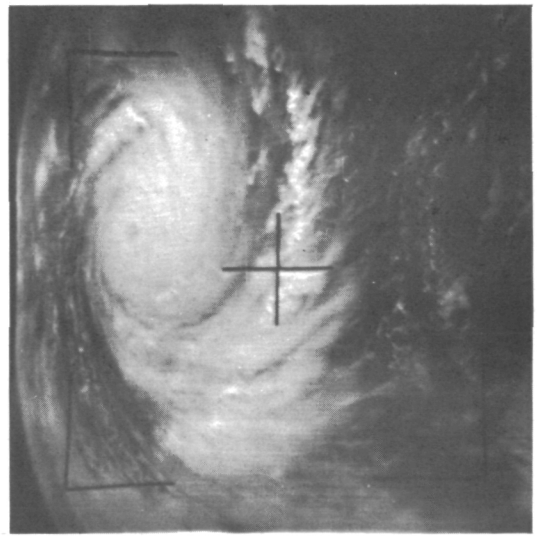
a. *Hurricane Odessa; Orbit 5800, Camera 1, Direct*



b. *Hurricane Ethel; Orbit 6704, Camera 2, Remote*



c. *Hurricane Gladys; Orbit 6748, Camera 2, Remote*



d. *Hurricane Hilda; Orbit 6952, Camera 2, Remote*

Figure III-7. Hurricanes Photographed by TIROS VII During 1964

Date	Storm
9/16	Typhoon Trix
9/16	Tropical Storm Virginia
9/27	Tropical Storm Agnes

In November 1965, Tropical Storm Faye was observed and tracked by TIROS VII, and in December TIROS VII was programmed in support of the Gemini 6.

Figure III-12 illustrates examples of storms taken by TIROS VII during 1965.

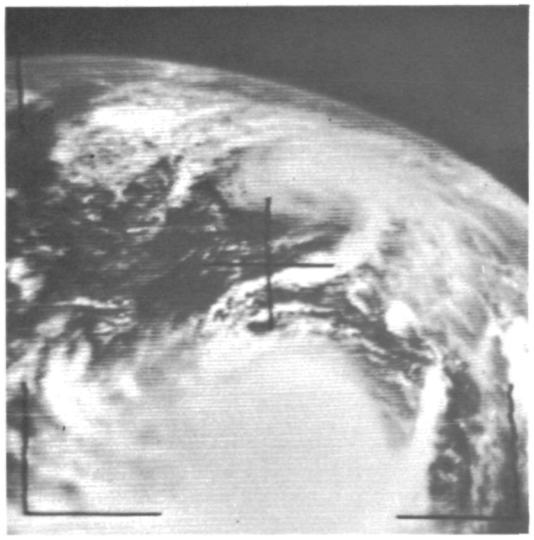


Figure III-8. Typhoons Kathy and Marie, Joined by Spiral Cloud; Orbit 6296, Camera 1, Remote

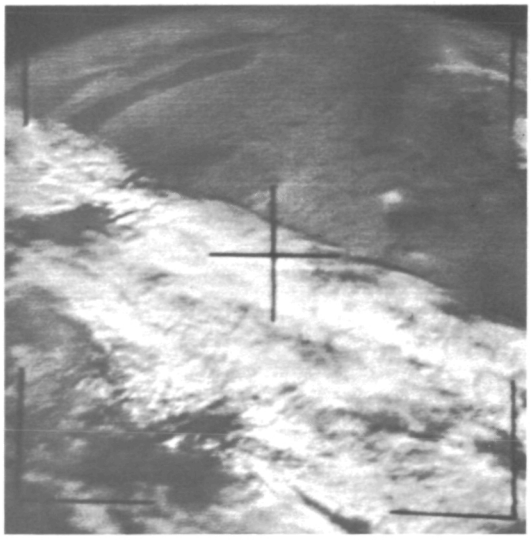
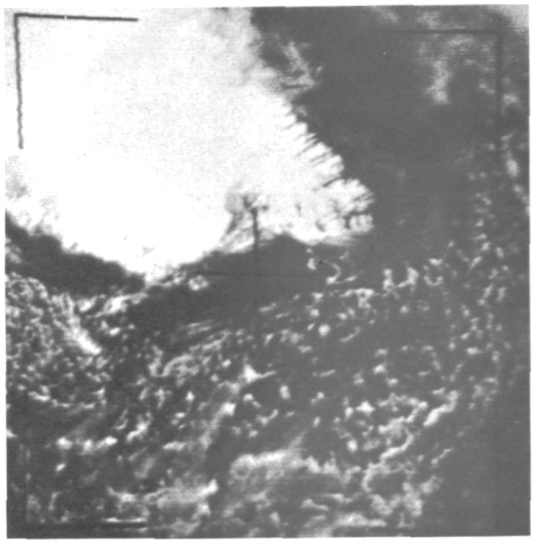
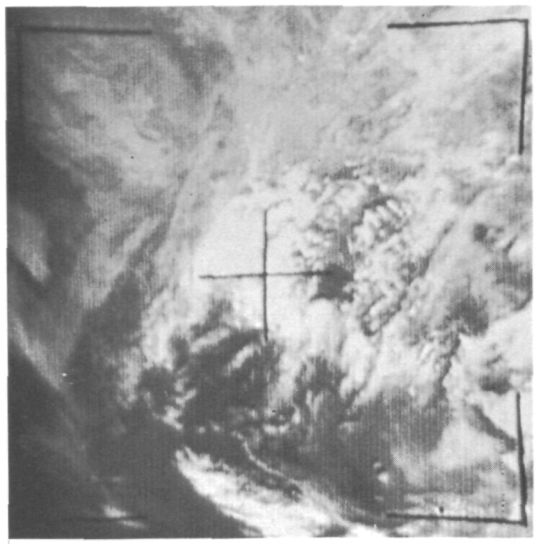


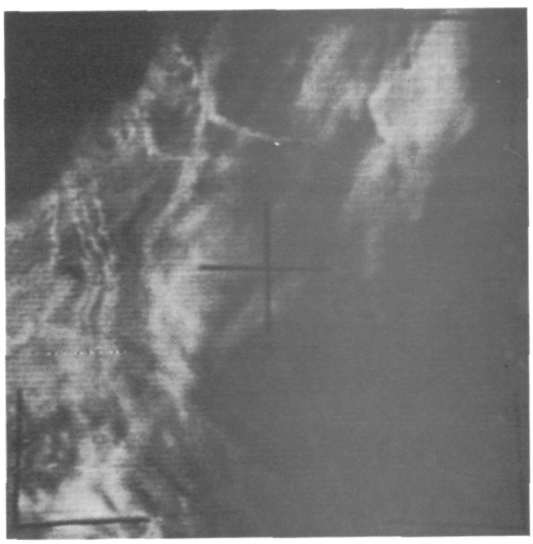
Figure III-9. Southwestern United States; Orbit 4792, Camera 1, Remote; Bright Spot Above Cloud Band is White Sands, New Mexico



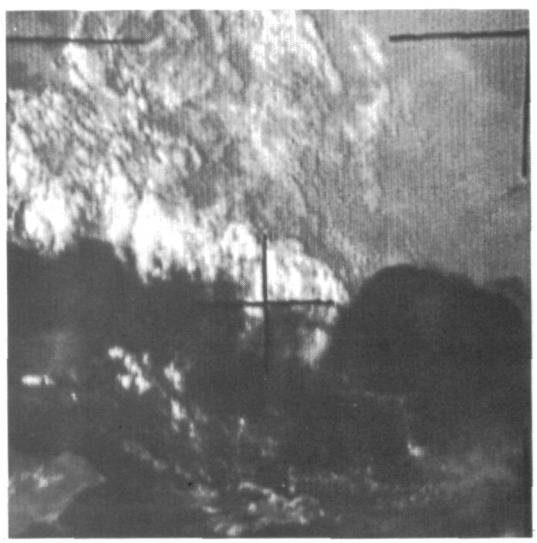
a. *Greenland; Orbit 5502, Camera 1, Remote*



b. *Smoke Column Near Santa Barbara, California; Orbit 6850, Camera 2, Remote*

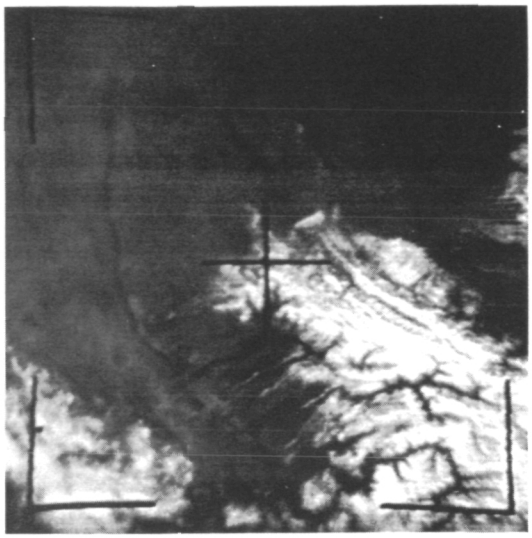


c. *Probable Aircraft Contrails, Southwest of San Diego; Orbit 7828, Camera 2, Direct*

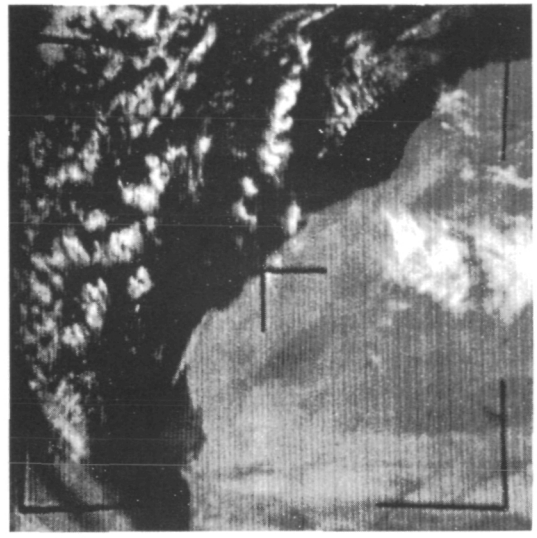


d. *Southern Arabia and Gulf of Aden; Orbit 7838, Camera 2, Remote*

Figure III-10. TIROS VII Pictures Taken During Second Half of 1964

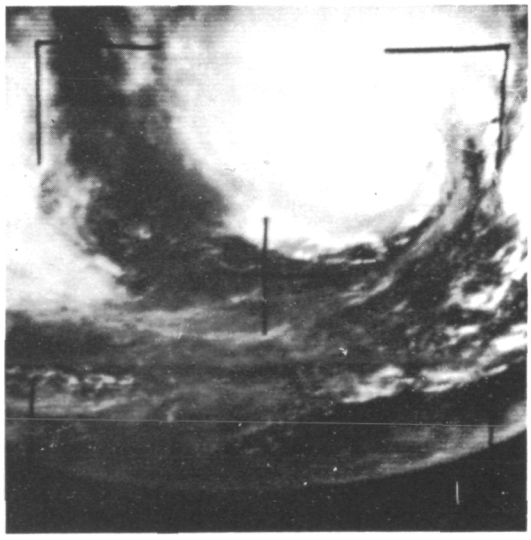


a. *Amudarya River and Snow-Covered Himalayan Mountains; Orbit 7922, Camera 2, Remote*

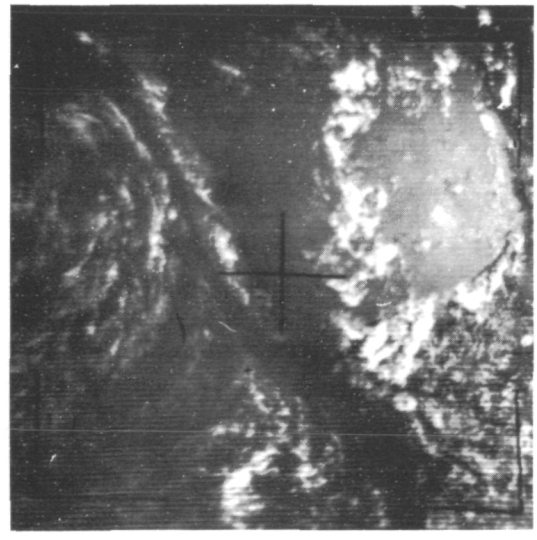


b. *Coast of West Africa; Orbit 8028, Camera 1, Remote*

Figure III-11. TIROS VII Pictures Taken During December 1964



a. *Typhoon Dinah, Orbit 10745*



b. *Edge of Tropical Storm Faye in Philippine Sea, Orbit 13124*

Figure III-12. Examples of Storm Pictures Taken During 1965

IV. SYSTEM DESIGN

The TIROS VII Meteorological Satellite System is fundamentally similar in design to the previous TIROS systems. The distinguishing elements in the TIROS VII design are as follows:

(1) Both TV cameras are provided with wide-angle lenses. This is the same lens configuration used on TIROS III. The other TIROS satellites have been provided with combinations of wide-and narrow-angle lenses (TIROS I and II) or wide- and medium-angle lenses (TIROS IV through VI). The TIROS VII television circuits are essentially the same as those used on TIROS VI but with minor circuit modifications.

(2) TIROS VII is the first satellite in the TIROS program to be provided with a command address capability.

(3) The TIROS VII satellite carries a redesigned (NASA) infrared ("heat mapping") experiment. The TIROS VII infrared experiment makes use of a new IR tape recorder and includes an electron temperature probe (ETP) experiment, as well as an omnidirectional IR experiment.

The structure of the TIROS VII spacecraft is nearly identical to that of the previous TIROS spacecraft although it is the most densely packed because of added experiments and equipment. An external view of the spacecraft is shown in Figure IV-1. It is approximately cylindrical in shape, with a diameter of 42 inches and a height (not including antennas) of 22.5 inches. With all components mounted, the spacecraft weighed 300.26 pounds, 19.76 pounds more than the TIROS VI spacecraft and 13.76 pounds more than the heaviest of the previous TIROS spacecraft, TIROS V. The spacecraft is an assembly of a circular baseplate, on which most of the components are mounted, and a hollow cover or "hat", containing the solar-cell array and dynamic control devices. The bottom of the baseplate is reinforced by radial and intercostal ribs. The hollow "hat" (open at the bottom) is fitted over the components and attached to the circumference of the baseplate. A four-element, crossed-dipole transmitting antenna array is attached beneath the baseplate and a single-element "whip" command antenna is mounted on the top surface of the hat, coaxial with the spin axis. The two television cameras project through the baseplate with their optical axes parallel to the spin axis.

The lateral surface of the spacecraft, although nearly cylindrical, actually consists of 18 flat, rectangular panels. A total of 9120 p-on-n silicon solar cells are mounted on

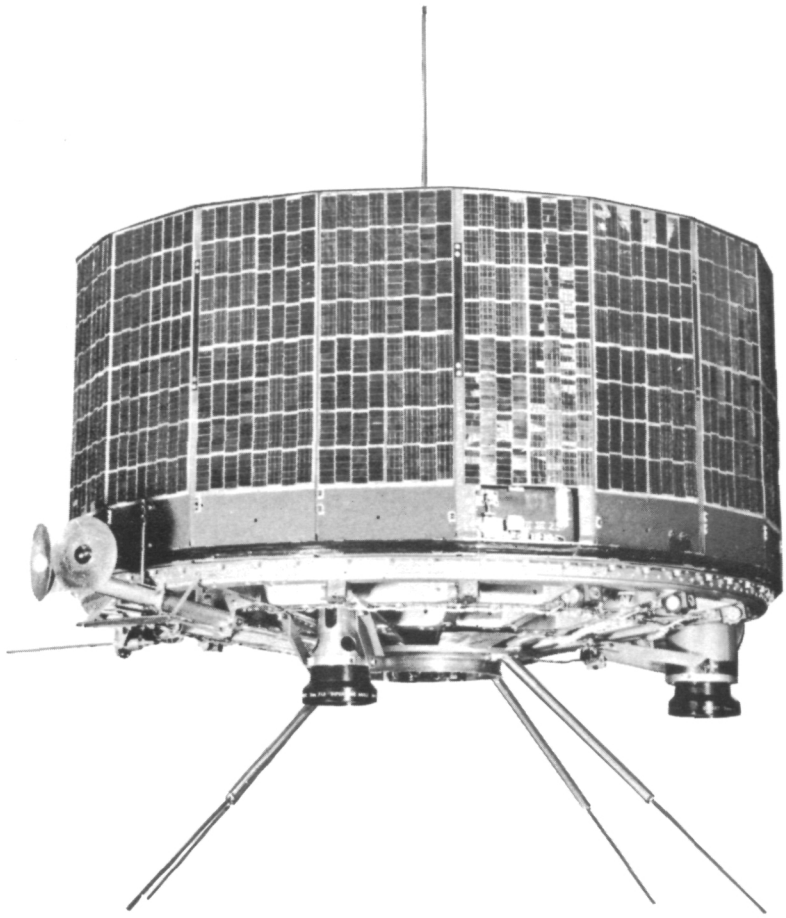
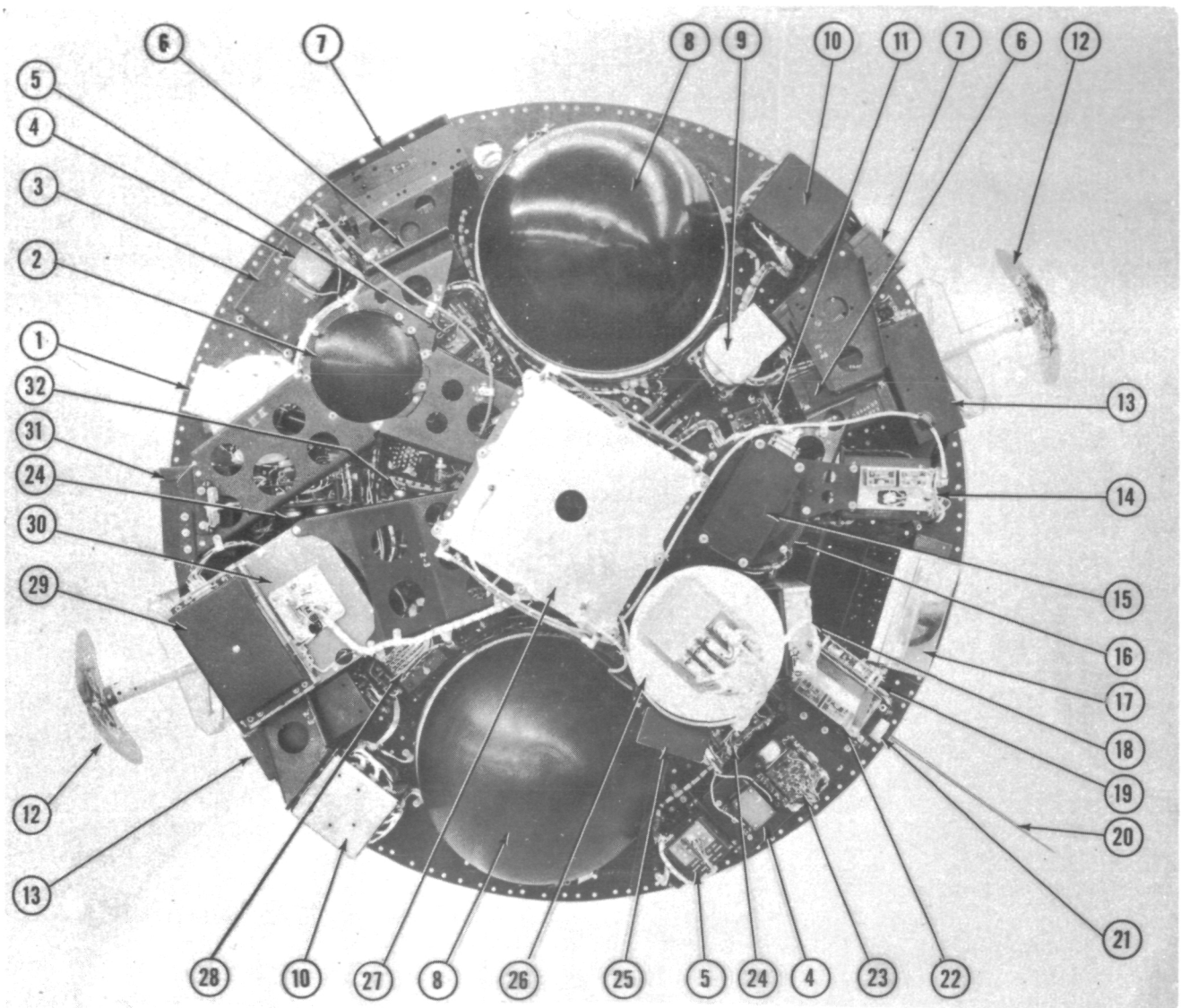


Figure IV-1. The TIROS VII Meteorological Satellite

the top and sides of the hat to convert solar energy to electrical energy to supply the satellite's power requirements. One-half of these cells are of "gridded" construction, to provide higher efficiency than the standard cells. (The standard cells have an efficiency of 7.25 percent; the gridded cells have an efficiency of 9.25 percent.)

Also prominent in the external appearance of the spacecraft are the narrow rod of the electron temperature probe (ETP) sensor and the two extension arms on which are mounted the sensors of the omnidirectional infrared experiment. These parts project radially from the baseplate. The use of the IR equipment on the TIROS VII spacecraft necessitated the relocation of the two 1-year timers. The timers were moved to the underside of the baseplate, diametrically opposite each other and recessed between the radial ribs. The separation ring, by means of which the spacecraft was attached to the third stage of the launching rocket, is located at the center of the underside of the baseplate. Illustrations of the TIROS VII baseplate, showing the components on top of the baseplate and fittings beneath the baseplate, are presented in Figures IV-2 and IV-3.

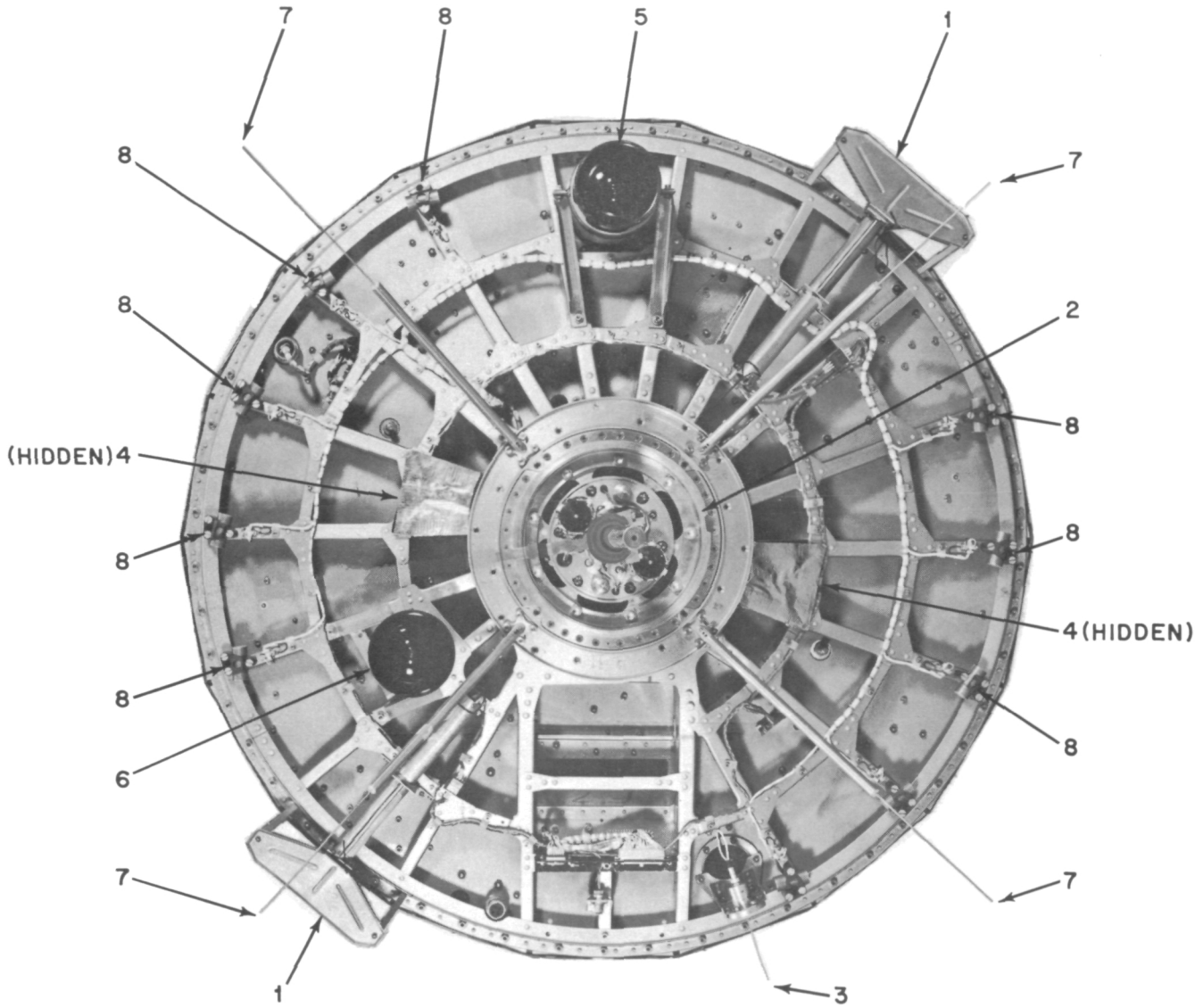
Each of the two redundant TV camera subsystems consists of (a) a 500-line, one-half inch, vidicon TV camera, (b) a camera electronics unit, (c) a magnetic video-tape



LEGEND

1. TV Camera No. 2
2. Electronic Clock No. 2
3. TV Transmitter No. 2
4. TV Transmitter Filter
5. TV Transmitter Power Converter
6. TV Camera Control Unit
7. TV Camera Electronics
8. TV Tape Recorder
9. TV Camera No. 1
10. TV Tape Recorder Electronics
11. IR Control Unit
12. Omnidirectional IR Sensor (Extended)
13. TV Tape Recorder Power Converter
14. Beacon Transmitter and (hidden) Command Receivers
15. Command Address Unit
16. Electronic Clock No. 1
17. Scanning IR Radiometer
18. Electron Temperature-Probe Electronics
19. IR Filter
20. Electron Temperature-Probe
21. Attitude Indicator
22. Beacon Transmitter
23. Attitude Control Switch and (hidden) TV Transmitter No. 1 and De-Spin Timer
24. Voltage Regulator
25. Omnidirectional IR Electronics
26. IR Electronics Canister
27. RF Matching and Coupling Network and (hidden) Storage Batteries
28. Telemetry Switch
29. "J" Tone Turn-Off Unit
30. IR Tape Recorder
31. Auxiliary Control Unit
32. Power Supply Protection Unit

Figure IV-2. TIROS VII Satellite, Top of Baseplate, Hat Removed



1. OMNIDIRECTIONAL IR SENSOR (RETRACTED)
2. SEPARATION RING
3. ELECTRON TEMPERATURE PROBE
4. ONE-YEAR TIMERS
5. TV CAMERA NO. 2
6. TV CAMERA NO. 1
7. ELEMENTS OF CROSSED DIPOLE TV AND BEACON TRANSMITTING ANTENNA
8. SPIN-UP ROCKET BRACKETS AND DUMMY ROCKETS

Figure IV-3. TIROS VII Satellite, Bottom of Baseplate

recorder, (d) tape recorder electronics, and (e) a TV transmitter. Each TV camera is provided with a wide-angle optical lens having a view angle of 104 degrees (diagonal). At the mean satellite altitude of approximately 395 statute miles, the lens provides an image on the vidicon faceplate of an earth area of approximately 500,000 square miles. This image is scanned at a horizontal rate of 250 cps and a vertical rate of 0.5 cps, to produce one complete 500-line scan in a 2-second read-out period. Scanning the square image area at a rate of 250 cps produces a video spectrum extending from d-c to a maximum of 62.5 kc (250 lines per second x 250 picture elements per line).

The output of each camera is either recorded on magnetic tape or transmitted directly to an interrogating ground station, depending on the programmed mode of operation. For the remote mode of operation, the camera control circuits are programmed to initiate camera operation after a specific delay in time corresponding to a position in orbit over an area of interest lying beyond the communications range of a ground station. The pictures taken in this mode are recorded and later, upon interrogation by a ground station, are played back and transmitted. The direct mode of operation is used while the satellite is in communication with a ground station. The pictures obtained in the direct mode were transmitted as they are taken, bypassing the tape recorder. In both modes of operation, the camera video signal is frequency-modulated on an 85-kc subcarrier. The lower sideband produced by this modulation is within the optimum frequency response of the tape recorder. The video subcarrier is frequency-modulated on a 235-Mc carrier for transmission to the ground station.

Each transmission of TV data, whether direct or played back from the tape, is accompanied by picture-orientation (sun-angle) data. This data is produced by a set of nine sun sensors equally spaced around the periphery of the satellite hat at 40-degree intervals from the 340-degree reference sensor. The sensors generate pulses as the satellite rotates, providing data which indicates the direction of the sun from the satellite at the time each picture is taken. At the nominal satellite spin rate of 10 rpm, three pulses occur in two seconds. This data, in conjunction with ephemeris data, is used to determine the sun direction in each TV picture. The pulses are modulated on a 10-kc subcarrier and recorded on a separate track on the video tape during remote operation. During direct operation, the data is modulated on the 10-kc subcarrier and combined with the TV subcarrier for direct transmission to the ground station.

The instrumentation control subsystem consists of the programming, communications, and control components necessary to provide remote control of the satellite. The control functions include both modes of TV camera operation, operation of the infrared subsystem, operation of satellite dynamics devices (spin rate and attitude), control of telemetry read-out, and control of beacon transmitters. The ground station portion of this subsystem provides for the programming of satellite operations in advance of a communications contact with the satellite and for the rapid, automatic generation and transmission of commands to the satellite during a contact. The satellite portion of the subsystem receive, demodulate, and distribute the commands to the individual control circuits in the satellite.

The satellite contains two beacon transmitters, one operating at 136.23 Mc and the other at 136.92 Mc. The beacons operated continuously during normal satellite operation, providing tracking signals to the ground stations. Provisions are included to turn off the beacons as an emergency measure (e.g., to conserve power) and to reactivate them at a later time. TIROS VII, like TIROS VI, also carries one-year timing devices to turn off both beacons permanently after a year's operation in orbit.

At the start of each satellite-to-ground contact, thirty-five of the satellite's most significant operating parameters and four calibration voltages are telemetered to the ground station by modulation of the beacon carriers. At all other times, the beacon carrier signals are modulated by attitude-indicator data (horizon pulses). The CDA and Minitrack Network stations track the beacon signals to determine satellite ephemeris data.

These stations also record and relay the attitude-indicator and the ephemeris data to the TIROS Technical Control Center (TTCC). The TTCC uses the data to predict the instantaneous satellite position for acquisition and tracking by the CDA and Minitrack Network stations, to predict satellite attitude, and to issue the proper programs to the CDA stations for transmission to the satellite.

The NASA infrared subsystem consists basically of a five-channel scanning radiometer (FCR), a magnetic tape recorder, a transmitter and a pair of omnidirectional radiometers. In addition, the University of Michigan electron temperature probe (ETP) experiment, for determining the density and temperature of electron particles in the satellite's space environment, is included in the infrared subsystem. The IR tape recorder used on previous TIROS satellites was replaced in TIROS VII by a tape recorder which was originally configured for the Nimbus satellite.

The scanning radiometer provides comprehensive data through measurements of returned heat energy in selected portions of the IR spectrum. The five sensors cover the following spectral ranges:

(1) 0.2 to 6 microns: the earth's albedo (reflected sunshine);

(2) 0.5 to 0.9 micron: the visible spectrum;

(3) 7 to 12 microns: the earth's radiation;

(4) 7 to 35 microns: the total radiation of the earth and its atmosphere; and

(5) 14.5 to 15.5 microns: the carbon dioxide content of the atmosphere.

The omnidirectional radiometer consists of two pairs of black and white sensors mounted 180 degrees apart on extension arms which project outward from the satellite in the plane of the baseplate. The black sensor is designed to measure (1) radiation from the sun, (2) reflected short-wavelength radiation from the earth, and (3) long-wavelength radiation in the infrared band from the earth. The white sensor is designed

to measure the long-wavelength reradiation from the earth. The combined measurements from the black and white sensors encompass the total spectrum of the earth's thermal-radiation characteristics.

The electron temperature probe (ETP) consists of a whip-like probe extending radially from the satellite's baseplate at the 10-degree position. This probe, in conjunction with its associated electronics, measures the temperature and density of electrons at the orbital altitude of the satellite.

The radiation and electron data are recorded continuously on the IR magnetic tape recorder except during a readout of the IR recorder. During a readout, the recorded data is played back and transmitted by the IR transmitter (235-Mc band) at an accelerated rate. The radiation and electron data being acquired during a playback of the recorder is transmitted directly to the ground stations at a non-accelerated rate over the IR transmitter. These direct transmissions occur simultaneously with the playback transmissions. This technique permits uninterrupted measurement of radiation data throughout the orbit. The IR subsystem also has provisions for recording and transmitting telemetric measurements of the temperature and pressure of the infrared (IR) package, the calibration voltages, and certain time reference signals.

The ETP power control, which was developed by AED for TIROS VII, is described in the classified supplement to the TIROS VII final engineering report.

The instrumentation control subsystem on TIROS VII is similar to that on previous TIROS satellites except for the addition of a command address capability to TIROS VII. The description of this subsystem is also contained in the classified supplement to the TIROS VII final engineering report.

Four devices for controlling satellite dynamics are included on the satellite; a precession damper, a de-spin mechanism, five pairs of spin-up rockets, and a magnetic attitude-control device. With the exception of the de-spin mechanism, these devices are of identical design to their counterparts used on the TIROS VI satellite. The release mechanisms for the de-spin weights were redesigned for the TIROS VII satellite to ensure a uniform tension in the cables prior to the release of the weights.

The satellite's operational spin rate of 8 to 12 rpm is dictated by a maximum, below which gyroscopic stabilization of the spin axis would begin to lose effectiveness. Satellite spin-down from the relatively high orbit-injection spin rate of 125 rpm, required for stabilization of the third-stage rocket, to the satellite operational spin rate was achieved by activation of the de-spin mechanism. This mechanism automatically released a pair of spin-reducing weights four to seven minutes after the satellite had separated from the third-stage rocket.

The precession dampers were uncaged after the separation of the satellite from the third-stage rocket to dampen any "wobble" caused by precession or nutation. The precession dampers proved effective in quickly reducing any wobble that accompanied the initial de-spin and any wobble produced by a later satellite spin-up.

Five pairs of spin-up rockets were installed about the periphery of the baseplate. The firing of these rocket pairs is controlled from the ground station, to increase the satellite spin rate after it has been reduced below the required minimum by interaction of the satellite's magnetic dipole with the earth's magnetic field.

The device for controlling satellite attitude consists of a 250-turn coil of wire, wound about the periphery of the satellite, and a 12-position switch that controls the magnitude and direction of the d-c current through the coil. In this manner, the satellite's magnetic-dipole strength and polarity are controlled by ground command. This control can move the spin-axis a maximum of 15 degrees per day using the torque produced by interaction between the satellite's magnetic field and the magnetic field of the earth.

Electrical energy for operation of the satellite's electronic circuits is provided by the solar-cell array and by storage batteries. During the "daylight" portion of the orbit, the solar array supplies the satellite's energy needs and maintains the batteries at full charge. During the "night-time" portion of the orbit, the batteries supply all electrical power to the satellite's subsystems.

The TIROS VII ground complex consists of three primary Command and Data Acquisition (CDA) stations, a back-up CDA station, and selected stations of NASA's Minitrack Network. One of the Minitrack stations, located at Santiago, Chile, provides a limited command (clock-start) capability to extend the remote picture-taking capability to orbits on which the satellite is out of contact with the CDA stations. The locations and the operations of various Minitrack Network stations in contact with the satellite are the same as for TIROS VI.

The three primary CDA stations command or program the satellite's picture-taking sequences, receive and process sun-angle and telemetry data, and receive and process the TV-picture and IR data transmitted by the satellite. The three CDA stations are located at Wallops Island, Virginia; San Nicolas Island, California; and Fairbanks, Alaska. The back-up CDA station, located at the Astro-Electronics Division of RCA, has the same capabilities as the primary CDA stations. This station has been used, as necessary, during the operational period of TIROS VII to perform engineering checks of satellite operation. In addition, the back-up station has assumed CDA station responsibility during periods of inoperability of the Wallops Island CDA station.

The stations of the NASA Minitrack Network track the satellite to obtain ephemeris data for use by the NASA TIROS Technical Control Center (TTCC) in formulating programming data and for use by the CDA stations for satellite acquisition or programmed tracking.

The areas of the earth to be photographed by the satellite are determined by the U. S. Weather Bureau and specified by request to NASA. These requests are then examined at the NASA TTCC, located at the Goddard Space Flight Center (GSFC), and become the basis for the operating programs prepared by TTCC. Detailed program instructions are teletyped from TTCC to the cognizant CDA station, where they are used in

programming the station's instrumentation control equipment. The program instructions specify the areas to be photographed, the camera system or systems to be used, the order in which the camera systems are to be used, and the number of "set-pulses" to be sent to the satellite's clocks so that remote picture-taking will begin at the desired point in the orbit.

When the satellite is within communication range of the CDA station, the preset command program is read out and transmitted to the satellite at high speed. High-speed transmission of the preset program commands allows time both for the playback of data that has been stored by the satellite and for the taking of direct pictures, during the relatively short period of each contact.

V. TV PICTURE SUBSYSTEM

A. FUNCTION

The TV-picture subsystem for TIROS VII consists of the satellite equipment for taking, storing, and transmitting television meteorological pictures and the ground equipment necessary for receiving, displaying, and recording the pictures. The satellite equipment consists of two identical and independent TV-camera systems. Each camera system is provided with an Elgeet wide-angle lens, with a 104-degree (diagonal) field-of-view. For a satellite altitude of 395 statute miles (the mean attitude of TIROS VII), this lens angle corresponds to a field-of-view of approximately 500,000 square miles for each picture.

Each camera consists of a 1/2-inch, 500-line vidicon TV camera, a camera-electronics package, a magnetic tape recorder, and a television transmitter. Each camera is capable of independent picture-taking in either of two modes. The direct mode of operation is used when pictures are to be taken while the satellite is within communication range of one of the CDA ground stations. In this mode, pictures are taken and, without being recorded, transmitted in real time directly to the interrogating ground station. When pictures are to be taken over an area of the earth remote from the CDA ground stations, the remote mode of camera operation is used. In this mode, the satellite is programmed to start taking pictures after a specific delay period (from 2 seconds to 5 hours), corresponding to the time required for the satellite to reach a position in its orbit over the area of interest. The pictures taken remotely are stored by the tape recorder until the satellite again comes within range of a CDA ground station. Upon interrogation of the satellite by a ground station, the recorded pictures are played back from the tape and transmitted over the TV transmitter.

In either mode of operation, the image focused on the faceplate of the vidicon camera tube is scanned at a horizontal (line) rate of 250 cps and a vertical (frame) rate of 0.5 cps to produce a 500-line, non-interlaced raster. The video signal generated by the scanning has a frequency range extending from d-c to a maximum of 62.5 kc (250 lines per second x 250 picture elements per line). This signal is amplified and frequency-modulated on an 85-kc subcarrier. During the direct mode of operation, the subcarrier is frequency modulated on the 235-Mc TV carrier for transmission to the ground. During remote operation, the subcarrier is recorded on tape and later, upon interrogation, played back and transmitted to the ground station.

Each TV transmission of direct or remote pictures is accompanied by sun-angle data that originates in the nine sun sensors, equally spaced about the periphery of the satellite. A separate 10-kc subcarrier, modulated on the 235-Mc TV carrier, conveys the sun-angle information. The sun sensors produce pulses of three characteristic

widths as the satellite rotates and each sensor, in turn, scans the sun. The pulse widths are assigned to the sensors in a manner such that a combination of any two consecutive pulses is unique and permits the orientation of the TV camera with respect to the sun to be determined. The pulses produced by the sensors are converted to 10-kc bursts of the same durations as the original pulses. In the direct mode of picture taking, these 10-kc bursts are combined with the video subcarrier before it is fed to the TV transmitter. During remote picture taking, the 10-kc bursts are recorded on a separate channel of the tape recorder. When the tape recording is played back for transmission of recorded data to the ground station, the 10-kc bursts are reconstituted (to ensure a sun-pulse sub-carrier frequency of exactly 10 kc) and then combined with the video sub-carrier. The combined video subcarrier and sun-angle signal are applied to the TV transmitter. This data, in addition to satellite attitude data, is used to determine the orientation of each picture frame. The sun-angle pulses are used also to measure satellite spin rate.

The TV transmissions from the satellite are received at the CDA ground station by a directional antenna and fed to two receivers connected for polarization-diversity reception. Bandpass filters are used to separate the video subcarrier from the sun-angle subcarrier. The video subcarrier is demodulated and the resultant signal is applied to video electronics circuits for display on a kinescope and to a magnetic tape recorder for storage. A time-reference output from the video electronics is applied to an index computer which generates a frame number, in binary form, for display with each picture. The index computer uses signals generated in the ground equipment to provide index data for identifying the camera or the tape recorder. The satellite, the orbit number, and the real time (GMT) associated with each picture are also displayed. The sun-angle data, after being separated from the video signal, is fed to a sun-angle computer. This computer provides sun-angle data, in binary form, which is displayed by a binary number-lamp presentation on a panel framing the kinescope screen. The kinescope screen, including the index and sun-angle data is photographed by a special 35-mm camera whose shutter is synchronized with the TV scanning signal.

In addition to the use of wide-angle lenses on both cameras, the TIROS VII TV-picture subsystem differs from the TIROS VI subsystem in four details:

(1) The filament of each vidicon tube is paralleled by a resistor to reduce filament current from 102 to 95 milliamperes and thus to extend vidicon filament life. The added resistor performs a second function by providing a means of distinguishing between a filament failure and a focus coil failure upon examination of the focus current telemetry. In the previous design, the focus coil and vidicon filament were in series, and a failure of either would result in total loss of focus current telemetry. In the new design, a parallel current path is provided which would permit focus current to continue flowing in the event of a filament failure. However, a focus coil failure would interrupt the flow of both filament and focus current.

(2) The input of the shutter drive circuit is modified to reduce sensitivity of the circuit to system noise. The value of the input resistor was changed from 100 kilohms to 10 kilohms, and the value of the input capacitor was changed from 0.01 microfarad to 0.0033 microfarad. These values were arrived at empirically.

(3) A metal excursion limiter was added to the motor driveshaft in each TV tape recorder to prevent excessive axial travel of the drive belt (which might occur during extreme vibration).

(4) The playback video amplifier in the tape recorder electronics was redesigned. Non-linear feedback is used in the new design to achieve a high degree of amplitude limiting and thus remove any unwanted amplitude variations arising from recording and playback.

The antennas and the coupling and matching network used on TIROS VII are identical in design to those used on the TIROS VI satellite.

The ground station equipment is essentially the same as that which was used for TIROS VI except for the addition of the command address capability.

B. PERFORMANCE EVALUATION

1. General

The performance of the TV picture subsystem throughout the first 18-month period covered by this report was excellent. Both camera systems performed without any recurrent malfunctions and with only very slight degradation of picture quality during the longest period of operation in the space environment attained by any meteorological satellite. The only functional anomalies encountered during this period have been of brief duration and random in occurrence, usually attributable to power supply status, coincidental switching operations, or some form of interference. The two evidences of degradation have been a slowly progressive horizontal decentering of the pictures taken by camera No. 1 and tape dropouts on the 32nd frame of the remote pictures taken by both cameras. The maximum decentering observed was 8.8 percent, an amount not great enough to detract from the usefulness of the pictures nor to prevent the corner reticle marks from appearing in all pictures. The tape dropouts were, for the most part, limited to two or three TV lines and because of the inherent redundancies and overlap of TV signals, have had little effect on the usefulness of the data.

From December 19, 1964 until October 15, 1965, both camera systems continued to provide good-to-excellent photographs. However, on October 15, 1965 pictures

received from camera system No. 2 were out of focus and the picture image appeared to have been rotated slightly. (This condition continued until January 31, 1966, when during an interrogation of orbit 14,144, pictures of good quality were again received from camera No. 2. The quality of camera No. 2 pictures remained good on an intermittent basis through March 21, 1966.)

Together, the two camera systems provided 122,328 TV pictures to the TIROS ground station during the 30 months of operation, of which 112,689 or 91.1 percent, were useful for meteorological interpretation and analysis. TIROS VII has been the most productive of the meteorological satellites in total pictures returned and in useable pictures returned. Examples of pictures taken by TIROS VII during the later months of this evaluation period are shown in Figures II-2, III-12, and V-1.

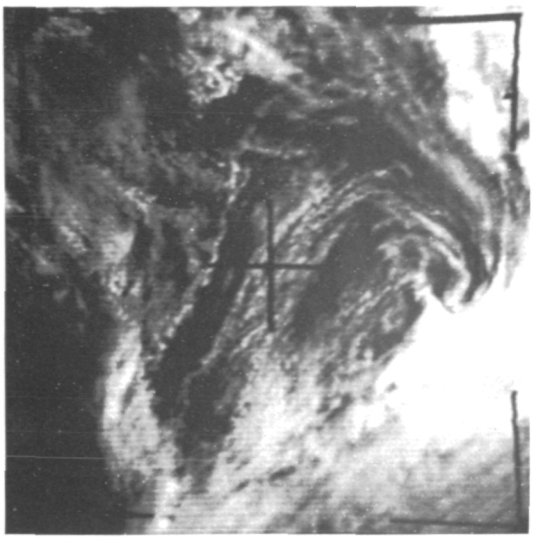
2. Camera System No. 1

a. General

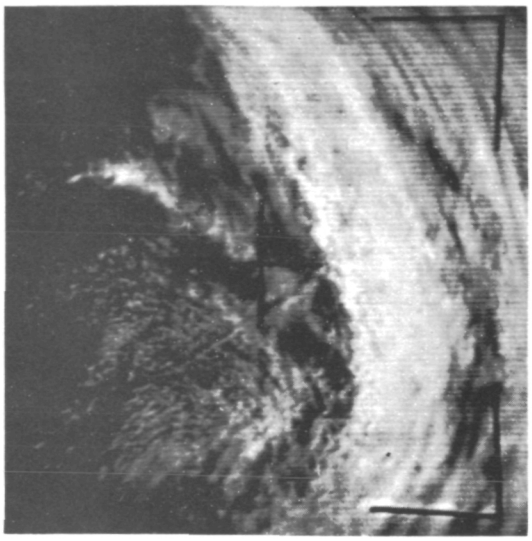
Camera system No. 1 returned 59,021 pictures during the 30-month period covered by this report. A total of 54,660 (94.3 percent) of these pictures were useful for meteorological analysis. In general, performance of this system has been excellent.

b. TV Camera and Camera Electronics

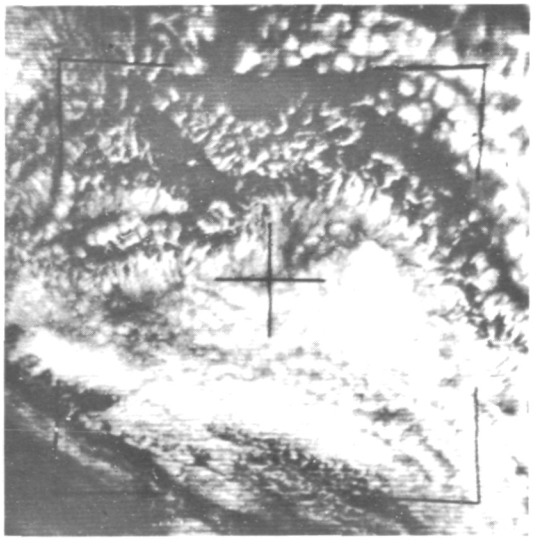
Camera No. 1 pictures from orbits spaced throughout the first 18-month period were projected and examined. Measurements were made of size, centering, and aspect ratio and the pictures were also inspected for general quality, presence of noise or interference, and any signs of abnormal camera performance. The percentage deviations from nominal values are listed in Table V-1. Figure V-2 shows how the deviation percentage is determined for each measurement. The only deviation of significant size that was encountered consistently was the horizontal centering deviation mentioned previously. This deviation varied from less than one percent during the early orbits to a maximum, on one orbit, of 8.8 percent. The size of the deviation varied, decreasing to as little as 1.5 percent even on late orbits. However, in general there was a tendency to increase with time. In the pictures examined the centering error remained under one percent up to orbit 248. Between orbits 248 and 454, the error range was between 0 and 4 percent. Between orbits 454 and 1388, the range was from 4 to 5.7 percent. Between orbits 1388 and 3487, the range was between 5.2 and 8.8 percent and between orbits 3487 and 8045 (the end of the period covered by the main body of this report) the error reached a high of 7.75 percent. An example representative of the most extreme decentering encountered is shown in Figure V-3. It is apparent in this example that the usefulness of the pictures was not impaired, even though the edge of the vidicon became visible as a tiny dark shadow in the lower left corner of some frames.



a. *Circulation Center in South Pacific, Orbit 8420, Camera No. 2*



b. *Frontal Band in South South Pacific, Orbit 8376, Camera No. 2*



c. *South Pacific, Orbit 10904, Camera No. 2*

Figure V-1. TIROS VII Pictures Taken During 1965

TABLE V-1. CAMERA SYSTEM NO. 1 PICTURE MEASUREMENTS

Orbit No.	Frame No.	Picture Mode	Centering Deviations (%)		Size Deviations (%)		Aspect Ratio Deviation (%)
			Horizontal	Vertical	Horizontal	Vertical	
19	4	D	0.6	1.8	1.9	5.4	6.6
19	13	D	0.6	0.6	1.9	2.4	4.5
92	2	T	2.4	0	0.6	4.3	4.6
92	10	T	0.6	0.6	1.9	5.3	3.1
92	34	T	3.0	0.6	0	3.0	3.9
102	1	T	0.6	0	1.9	4.3	3.1
102	27	T	0.6	0.6	2.1	4.5	3.0
117	10	D	0.6	0.6	1.9	4.3	3.1
117	29	D	0	0.6	2.1	5.5	3.0
161	3	T	0.6	0	2.1	2.4	1.5
161	19	T	0.6	0	2.1	2.4	1.5
190	1	T	0	0	2.4	4.1	2.3
190	15	T	0	0	2.4	4.8	3.0
248	1	T	0	0	1.5	4.1	2.3
248	12	T	0	0	1.5	2.6	1.5
357	8	T	1.8	0	1.2	0	0
357	24	T	1.6	0	0.8	0	1
454	13	T	4.0	0	0.2	0	0
454	16	T	3.5	0	0.4	0	2.0
513	8	T	4.0	0	0.5	0	1.9
513	24	T	4.3	0	0.5	0	1.9
533	8	T	4.3	0	0.2	0	0
533	24	T	3.6	0	0.4	0	2.3
541	8	D	4.6	5.3	0	1.2	0
541	24	T	3.6	0	0	0	1.8
541	8	T	4.1	1.4	0.5	2.2	1.0

TABLE V-1. CAMERA SYSTEM NO. 1 PICTURE MEASUREMENTS (Continued)

Orbit No.	Frame No.	Picture Mode	Centering Deviations (%)		Size Deviations (%)		Aspect Ratio Deviation (%)
			Horizontal	Vertical	Horizontal	Vertical	
562	1	T	3.9	1.5	0.4	2.5	1.4
562	16	T	3.5	0	0.2	0	1.9
562	32	T	3.7	0	0.2	0	4.1
629	1	T	4.0	2.2	0.5	3.0	1.0
629	16	T	2.9	0	1.0	5.0	3.6
629	32	T	3.3	0.4	1.6	5.0	6.2
892	2	T	4.4	2.2	0.4	2.2	1.0
892	16	T	3.6	0.7	0.4	2.2	1.0
892	26	T	4.4	0.7	1.0	3.6	2.0
1006	1	T	4.5	1.0	0.1	3.4	2.6
1006	16	T	4.8	0.3	0.4	3.4	1.7
1130	1	T	5.0	0.4	1.4	5.3	2.7
1130	16	T	5.0	1.4	1.4	4.6	2.7
1130	29	T	5.4	0.4	2.0	4.9	3.6
1276	2	T	6.1	2.2	1.3	2.5	1.0
1276	16	T	5.0	1.4	1.0	3.3	2.8
1276	32	T	4.7	1.4	1.3	6.9	5.2
1388	1	T	5.7	1.4	1.8	1.6	0
1388	16	T	5.7	1.4	1.8	2.5	1.0
1388	31	T	5.7	0.7	1.0	4.6	4.5
1449	2	T	2.5	2.3	0.6	3.2	3.5
1449	16	T	2.9	1.4	0.3	1.2	0
1449	32	T	2.7	2.3	0.6	1.0	0.3
2028	6	T	6.3	1.8	0.4	1.6	1.0
2028	31	T	5.2	1.1	0.1	3.9	1.0

TABLE V-1. CAMERA SYSTEM NO. 1 PICTURE MEASUREMENTS (Continued)

Orbit No.	Frame No.	Picture Mode	Centering Deviations (%)		Size Deviations (%)		Aspect Ratio Deviation (%)
			Horizontal	Vertical	Horizontal	Vertical	
2495	4	T	5.5	1.8	0.0	3.0	1.8
2495	31	T	5.2	0.7	0.2	4.0	2.6
2874	2	D	6.5	3.4	1.2	0	3.5
2874	28	T	5.3	0.7	0.9	6.0	4.4
3173	2	T	8.8	1.8	1.5	2.4	2.0
3173	31	T	8.8	1.1	0.7	0	0
3210	4	T	7.3	0	0.9	0.6	1.0
3210	32	T	6.6	0.7	0.9	3.5	6.0
3268	8	T	7.1	0.4	0.4	0.8	2.7
3268	17	T	7.8	1.0	0.4	0	3.0
3487	9	T	6.4	1.4	1.5	2.9	1.9
3487	31	T	5.6	0.3	1.0	4.5	3.6
3503	16	T	5.1	2.6	0	3.9	3.3
3503	25	T	4.2	2.0	0	3.4	3.3
3503	30	T	4.7	1.1	0.7	3.9	2.0
4238	6	T	4.1	1.1	0.7	0.2	1.8
4238	17	T	3.2	0.3	0.9	0.3	0.6
4238	32	T	2.8	0.2	1.6	0.1	0.6
4555	8	T	6.3	1.4	1.0	3.9	3.6
4555	16	T	6.3	0.7	1.0	4.6	4.4
4555	24	T	6.3	0.7	1.0	5.3	5.3
4555	32	T	5.9	0.7	0.5	6.6	6.9
4748	6	T	6.2	2.6	1.6	4.4	2.7
4748	16	T	5.3	2.5	1.6	5.1	3.7
4748	30	T	6.5	3.0	2.4	4.1	2.4

TABLE V-1. CAMERA SYSTEM NO. 1 PICTURE MEASUREMENTS (Continued)

Orbit No.	Frame No.	Picture Mode	Centering Deviations (%)		Size Deviations (%)		Aspect Ratio Deviation (%)
			Horizontal	Vertical	Horizontal	Vertical	
5503	6	T	4.4	1.1	2.8	4.6	2.7
5503	16	T	6.8	1.5	3.1	3.6	1.8
5503	27	T	4.6	2.8	2.0	2.5	0.6
5503	34	D	4.6	2.3	1.7	2.9	2.6
5755	5	T	4.3	1.8	0.4	0.2	3.0
5755	17	T	4.4	0.7	0.8	0.8	3.5
5755	31	T	4.5	2.3	0.1	4.4	5.3
5973	2	T	6.8	0.2	0	2.5	2.4
5973	16	T	6.4	0.2	1.1	1.4	1.9
5973	28	T	7.2	0.2	0.2	0.5	1.3
6509	2	D	7.9	3.1	0	1.4	4.4
7009	5	D	5.6	2.6	0.1	0.5	4.5
7009	17	T	5.6	1.5	1.0	1.3	2.3
7009	8	T	4.7	1.4	1.0	0.3	3.3
9229	10	T	5.3	0.4	1.0	2.0	1.4
9229	2	T	5.2	2.2	1.0	2.0	0.3
9229	1	T	5.0	1.9	1.0	1.5	0.7
9811	21	T	4.4	1.3	3.5	5.0	4.9
10833	5	T	5.6	1.1	1.3	4.1	2.6
10833	10	T	4.8	1.1	2.1	3.8	1.7
10833	13	T	4.8	1.9	0.2	4.4	2.6
11410	7	T	4.1	0.1	0.7	1.4	11.1
11410	8	T	4.2	0.4	2.5	1.7	8.0
11410	12	T	7.0	0.1	0.3	0.8	1.2

TABLE V-1. CAMERA SYSTEM NO. 1 PICTURE MEASUREMENTS (Continued)

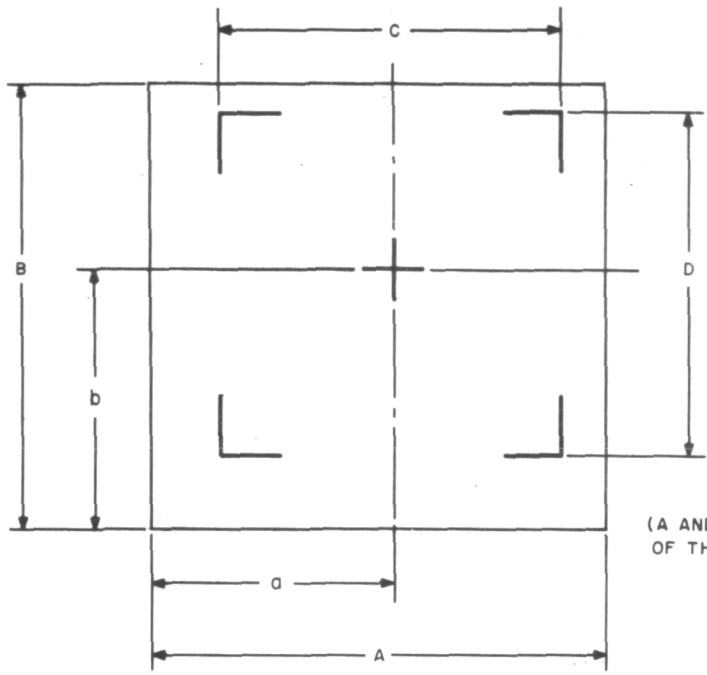
Orbit No.	Frame No.	Picture Mode	Centering Deviations (%)		Size Deviations (%)		Aspect Ratio Deviation (%)
			Horizontal	Vertical	Horizontal	Vertical	
12856	28	T	6.2	1.7	2.0	2.9	1.2
12856	29	T	6.0	2.1	1.3	3.6	1.8
12856	31	T	6.3	2.1	2.1	4.0	2.0
13241	4	T	7.9	1.6	0.7	0.2	4.6
13241	5	T	5.9	1.6	0.6	0.4	3.2
13241	12	T	5.8	2.1	1.1	1.7	3.0
14437	16	T	1.1	1.4	0.9	3.4	5.1
14437	19	T	1.8	0.5	0.7	3.0	4.4
14437	22	T	7.3	1.1	0.1	3.9	5.0

The horizontal centering error is believed to be related to a temperature gradient within the satellite that began on orbit 300 and lasted until sometime between orbits 600 and 650. Before this change the baseplate temperature was approximately 3.5°C, where it had remained for the first 300 orbits. After orbit 300, the temperature increased, reaching 21°C on orbit 360, where it stayed with small variations (the maximum temperature was 25°C) until orbit 600. After orbit 600, the baseplate temperature decreased until it reached the original value of 3.5°C. Although this temperature variation is well within the normal operating range of the camera (0 to 50°C), it is possible that a component in the horizontal deflection circuit developed excessive drift with temperature, causing a shift in vidicon voltages. A second possibility is that the temperature change caused a change in the repetition rate or width of the horizontal synchronizing pulse, either of which could result in a centering change.

Deviations from nominal values of the other picture measurements also increased with time in space but to a much lesser extent. The vertical centering error never exceeded 3.4 percent and was generally less than 3 percent. Horizontal size error was never greater than 3.08 percent and was generally less than 2.5 percent. The vertical size error did not exceed 6.9 percent and was generally less than 4.5 percent. The largest aspect ratio error was 6.6 percent, and in most of the pictures examined, was less than 6 percent.

c. Tape Recorder

Camera No. 1 remote pictures from orbits throughout the evaluation period were examined for evidence of tape recorder performance; the pictures were



$$\% \text{ HORIZONTAL CENTERING ERROR} = \frac{2a - A}{2A} \times 100$$

$$\% \text{ VERTICAL CENTERING ERROR} = \frac{2b - B}{2B} \times 100$$

$$\% \text{ HORIZONTAL SIZE ERROR} = (0.75 - \frac{C}{A}) \times 100$$

$$\% \text{ VERTICAL SIZE ERROR} = (\frac{D}{B} - 0.75) \times 100$$

$$\% \text{ ASPECT RATIO ERROR} = (1 - \frac{C}{D}) \times 100$$

Figure V-2. Calculation of Deviation Percentages in TV Pictures

examined for flutter and wow, signal dropouts, interference, and general quality insofar as it is influenced by tape recorder performance.

The pictures examined showed that the camera system No. 1 tape recorder performed very well throughout 30 months of operation in orbit. On most of the frames examined, flutter and wow were too small to be discernible. On a small number of frames, two cycles of a 14 cps time-base modulation, apparently flutter, appeared at regularly spaced intervals of approximately four occurrences per frame. The maximum peak-to-peak amplitude of the 14 cps signal was 0.7 percent of the horizontal line length. This small flutter is thought to be a consequence of the telemetry readout coinciding with remote picture playback and is not indicative of any malfunction.

No recurrent anomalies were present in pictures from the early orbits. After orbit 4000 (approximately 9 months after launch), frame 32 (the first frame to be recorded

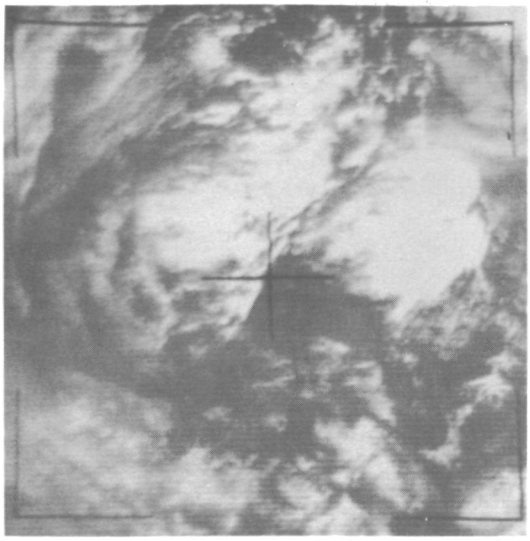


Figure V-3. Remote Picture by Camera No. 1 on Orbit 2043, Showing Extreme Example of Horizontal Decentering, Edge of Vidicon is Visible as Dark Triangle in Lower Left-Corner

and the last to be played back) in many of the remote sequences contained tape dropouts. An example is shown in Figure IV-4. These dropouts are believed to have occurred when the first remote picture was recorded on a portion of the tape containing imbedded shreds of the mylar base material that had been scraped from the tape as it passed under the end-of-tape sensor. Although these shreds were scraped from the non-recording side of the tape, they contacted, and became imbedded in, the recording side of the tape at the position of frame 32 when the tape was wound on the take-up reel.

A very small number of the frames examined showed the effects the local radio interference at the ground stations, including the uniform dot pattern of pulse radar transmissions and various herringbone patterns. None of these interference patterns was caused by any anomaly of the subsystem or of other subsystems on the satellite.

d. TV Transmitter

The camera system No. 1 235-Mc TV transmitter performed normally throughout the period of evaluation. Signal strengths reported by the CDA ground stations indicated that power output of the transmitter was greater than the specified minimum of two watts. The consistently good quality of the TV pictures received from this system indicated proper modulator performance.

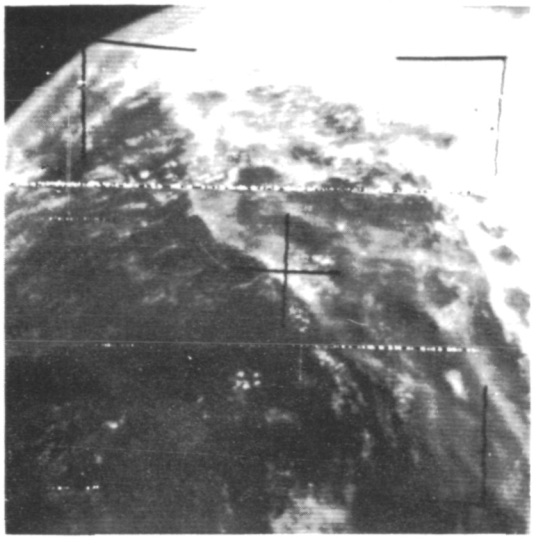


Figure V-4. Frame 32 of Camera No. 2 Remote Sequence on Orbit 8073, Showing Tape Dropouts

3. Camera System No. 2

a. General

Camera system No. 2 returned 63,037 pictures during the 30-month period of evaluation covered by this report. Altogether, 58,029 (92.1 percent) of the pictures returned were useful for meteorological analysis. The performance of this camera system was generally very good.

b. TV Camera and Camera Electronics

Pictures returned by camera No. 2 throughout the first 18 months of evaluation period were projected for detailed examination and measurements were made of centering, size, and aspect ratio of each picture. The pictures were also examined for general quality and any evidence of camera system anomalies. Deviations of the measured values from the nominal values, expressed as percentages (Figure V-1), are listed for all of the measurements in Table V-2.

In all of the pictures examined, the specified overall linearity requirement of $\pm$ 10 percent was met. No individual deviation was excessive and none of the deviations observed reduced picture usefulness.

TABLE V-2. CAMERA SYSTEM NO. 2 PICTURE MEASUREMENTS

Orbit No.	Frame No.	Picture Mode	Centering Deviations (%)		Size Deviations (%)		Aspect Ratio Deviation (%)
			Horizontal	Vertical	Horizontal	Vertical	
1	8		3.7	1.2	0.6	1.1	0
1	14		2.1	0	0.2	1.1	0
19	3	T	4.3	0	1.3	0	0
34	3	D	2.1	0.6	0.2	2.4	4.6
34	18	D	2.4	0	0.3	2.4	4.6
34	22	T	2.4	0	0.6	2.4	2.4
92	3	D	1.2	0	1.2	0	0
102	2	T	3.0	0.6	0.9	2.1	1.5
248	3	T	2.9	0.6	0.4	2.4	1.5
248	15	T	2.9	0.6	0.4	3.5	3.0
248	31	T	3.5	0.0	0.4	2.6	3.0
404	3	T	1.8	0.7	0.2	0.4	1.0
459	16	T	0.7	0	0.5	0	4.0
562	18	T	0.9	1.5	1.0	0.7	0.4
562	31	T	1.1	0.4	1.2	2.8	4.0
649	1	T	0.7	0	0.4	3.0	2.8
649	16	T	0.7	0.7	0.4	5.0	5.5
649	32	T	0.7	0.7	0.4	5.1	5.5
892	2	D	1.4	2.2	0	0.4	2.0
892	18	D	0	2.2	0	2.5	4.6
1056	8	T	0.3	0.7	0.5	1.0	0
1056	16	T	0.3	1.4	0.8	2.0	1.8
1056	31	T	0.3	0.3	0.8	3.0	3.5
1130	5	T	1.2	1.4	0.5	2.1	2.8
1130	15	T	0	1.4	0	2.9	3.6
1130	31	T	0.7	0	0	2.9	3.6

TABLE V-2. CAMERA SYSTEM NO. 2 PICTURE MEASUREMENTS (Continued)

Orbit No.	Frame No.	Picture Mode	Centering Deviations (%)		Size Deviations (%)		Aspect Ratio Deviation (%)
			Horizontal	Vertical	Horizontal	Vertical	
1276	2	D	0	2.1	0.4	1.8	4.5
1276	6	D	0.4	2.5	0.5	2.4	3.6
1402	1	T	1.2	0.7	1.0	2.4	1.9
1402	16	T	0.7	0.7	0.4	3.1	2.8
1402	31	T	0.7	1.4	0.4	2.5	2.8
1449	1	T	0.3	3.2	0.5	1.2	1.4
1449	16	T	0.3	0.5	1.2	0.8	2.1
1449	31	T	0.6	1.5	0.5	1.1	2.1
2005	2	T	1.2	1.3	1.3	1.4	4.0
2005	16	T	0.5	0.5	0.8	0.1	2.8
2028	2	T	0.4	0	0.1	1.0	2.0
2028	31	T	1.0	1.1	0.9	2.4	0
2268	2	D	1.9	3.0	1.0	0	1.0
2268	24	T	1.9	0	0.1	4.5	4.0
2349	2	T	1.0	0.3	1.5	3.4	1.0
2349	31	T	1.0	0.7	0.1	3.5	3.0
3006	2	T	2.0	0.5	0.2	0.3	1.6
3006	16	T	1.5	1.9	0.2	1.0	0
3006	28	T	1.5	1.0	0.2	0.5	0
3006	1	D	1.5	3.6	0.6	0.1	0
3010	3	T	1.5	0.7	0.8	2.1	0.6
3010	16	T	1.5	0.2	0.2	0.6	0.6
3010	32	T	1.5	0.2	1.0	1.6	1.3
3769	9	T	1.8	0.3	0.9	0.6	1.7
3769	20	T	2.3	1.2	0.1	0.1	2.0
3769	30	T	2.8	1.8	0.1	0.8	1.3
3998	2	T	1.3	0.1	0.5	1.3	4.3

TABLE V-2. CAMERA SYSTEM NO. 2 PICTURE MEASUREMENTS (Continued)

Orbit No.	Frame No.	Picture Mode	Centering Deviations (%)		Size Deviations (%)		Aspect Ratio Deviation (%)
			Horizontal	Vertical	Horizontal	Vertical	
3998	15	T	1.3	1.8	0.7	1.4	4.0
3998	6	D	3.0	2.2	0.6	1.0	3.9
4250	1	T	1.5	0.1	0.9	0.9	1.7
4250	16	T	0.9	1.1	0.9	0.1	1.4
4250	30	T	2.0	0	0	0.3	2.3
4496	16	T	2.6	0.8	0.4	0.9	1.3
4496	30	T	2.6	1.2	0.1	1.0	3.4
5026	16	T	2.3	0.3	1.0	1.0	1.7
5026	31	T	3.3	0.4	1.5	0.1	1.7
5755	2	T	2.2	0.6	0.4	0.3	4.5
5755	2	T	3.2	0.2	1.3	0.5	4.5
5755	31	T	1.6	0.2	0.1	1.0	2.0
6230	2	T	1.6	2.0	0.8	2.3	5.0
6755	2	T	1.5	1.4	0.4	0.4	3.9
6755	16	T	2.3	1.0	0.9	1.0	2.0
6755	28	T	1.8	1.0	1.0	0.1	2.3
7942	2	T	2.9	1.2	0.3	0.3	2.0
7942	16	T	2.0	1.7	1.4	0.1	3.5
7942	32	T	2.5	2.0	0.8	1.0	3.2
8045	5	T	1.7	0.7	0.7	1.8	4.0
8045	17	T	2.0	0.7	1.1	0.9	2.5
8045	26	T	3.0	0.9	0.7	2.6	1.6
9635	8	T	1.8	0.8	2.1	5.9	1.2
9973	5	T	2.9	1.3	0.5	0.4	1.0
9973	6	T	1.8	1.8	0.8	1.6	0.3
10177	4	T	1.7	1.3	0.8	2.9	2.3
10177	9	T	1.6	1.9	1.1	2.7	1.4

TABLE V-2. CAMERA SYSTEM NO. 2 PICTURE MEASUREMENTS (Continued)

Orbit No.	Frame No.	Picture Mode	Centering Deviations (%)		Size Deviations (%)		Aspect Ratio Deviation (%)
			Horizontal	Vertical	Horizontal	Vertical	
10177	16	T	1.0	6.3	1.0	3.1	2.6
11270	5	D	2.3	3.8	0.4	1.4	2.3
11270	8	D	1.7	4.4	1.1	1.5	1.5
11270	2	D	1.5	3.5	1.5	2.9	3.7
12024	7	T	2.4	2.1	0.8	2.3	0.5
12024	8	T	2.6	1.7	1.0	1.3	0.1
12024	9	T	2.5	2.2	1.7	2.9	0.3
14305	1	T	1.7	4.8	0.0	6.1	0.0
14305	2	T	1.1	4.7	0.6	7.3	1.5
14305	4	T	1.6	4.8	0.1	6.5	1.1

The deviations did exhibit a slight tendency to increase with time in orbit. The horizontal centering error had an average value of 0.5 percent for the first 500 orbits. From orbit 500 to 3500, this error reached a maximum of 2 percent. Between orbits 3500 and 8045 (the last orbit for which pictures were examined), the error reached 3.33 percent.

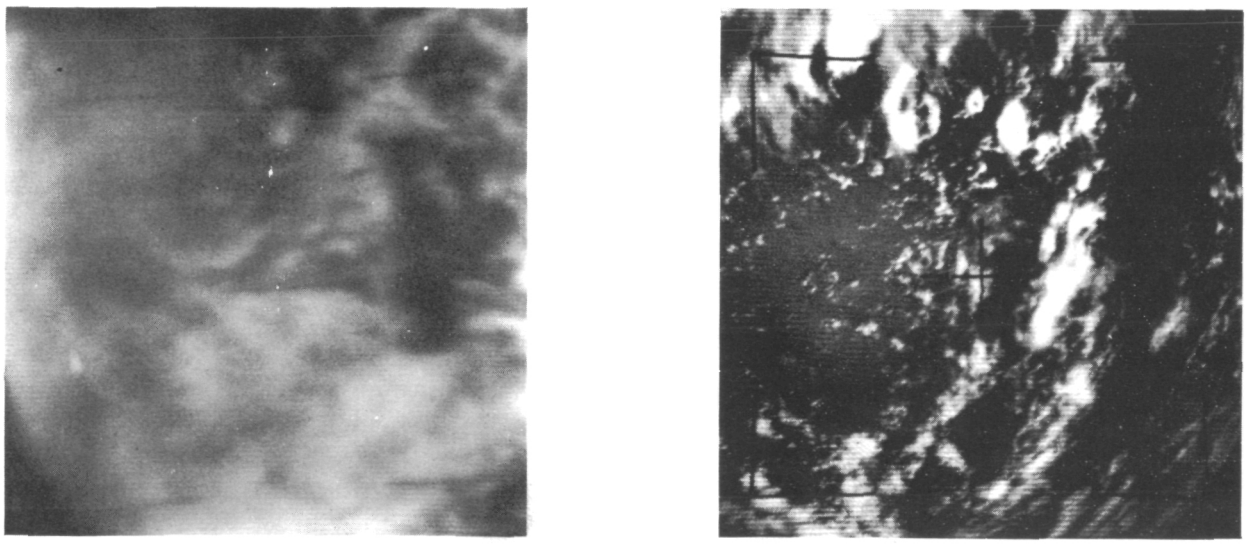
The vertical centering error averaged 0.5 percent for the first 649 orbits and 1.3 percent from orbit 892 through orbit 1402. From orbit 1450 until the end of the evaluation period, the maximum vertical centering error was 3.62 percent. The horizontal size error remained below 2 percent during the entire evaluation period. The vertical size error was constant at 2.4 percent for the first 1400 orbits, increased to a maximum of 5.1 percent between orbits 1400 and 3487, and was less than 2.6 percent from orbit 3487 to the end of the 18-month period.

The aspect ratio error was a maximum of 2.8 percent during the first 1400 orbits and a maximum of 4 percent up to orbit 3487. Between orbit 3487 and the end of the first 18-month period, the aspect ratio error was a maximum of 4.46 percent.

None of the deviations in the camera No. 2 measurements was large enough to suggest any significant degradation.

Camera subsystem No. 2 returned pictures of good quality until October 15, 1965. When during an interrogation of orbit 12,554 by Fairbanks station, 30 unprogrammed pictures were received from the No. 2 tape recorder. All frames were out of focus to the extent of being unusable for meteorological purposes, and the picture image appeared to have been rotated slightly in a counterclockwise direction. Pictures received from subsystem No. 2 during subsequent interrogations exhibited the same type of distortion. See Figure V-5. (On January 31, 1966 during an interrogation of orbit 14,144, pictures of good quality were again received from camera No. 2. See Figure V-5.)

The anomaly in camera system No. 2 was investigated at RCA. Since the probable cause of the defocussing, raster rotation, and raster size change in the camera was either an increase of vidicon high voltage or a decrease of focus current, telemetry data for these two parameters was accumulated. An analysis of the data indicated that the average vidicon high-voltage telemetry reading was approximately 13.2 percent higher after the appearance of the anomaly than before. To further investigate this indication that a change in vidicon high voltage, rather than in focus current, was



a. *Picture Showing Degradation of Camera No. 2, Orbit 12598, October 18, 1965*

b. *Picture Showing Recovery of Camera No. 2, Orbit 14144, January 31, 1966*

Figure V-5. TIROS VII Pictures from Camera No. 2

responsible for the picture degradation observed, a test camera was set up and high-voltage values above normal were applied to it. The changes in vertical size and in raster rotation of the test camera for two increased values of high voltage are compared with the parameter changes of the TIROS VII camera in the following tabulation:

	Parameter Change	
	Vertical Size	Rotation
TIROS VII Camera No. 2	2.6%	4.1°
Test Camera (10% High Voltage)	2.5%	3.1°
Test Camera (+13.7% High Voltage)	2.4%	2.9°

The tabulated data shows that a high-voltage increase in the test camera equal to that which was indicated by telemetry data to have occurred in the TIROS VII camera produced a greater size change but a lesser change in picture rotation. The difference in these effects can be attributed to the difference in the vidicons and yokes as well as to measurement errors, and the data thus indicates that the camera anomaly on TIROS VII was due to an increase in the vidicon high voltage. An increase of this magnitude could have been caused by an active component malfunction in the input regulator.

The input regulator no longer regulates the voltage to the vidicon high-voltage power supply, but rather applies a voltage to the vidicon which varies with the load-bus voltage. Therefore, if the load-bus voltage is high, there is an increase of vidicon high voltage; if the load-bus voltage is lower, the reverse is true. However, whenever the vidicon high voltage is within the normal voltage range, pictures of good quality are obtained from camera No. 2, and when the vidicon high voltage is below or above the normal operating voltage, poor pictures are obtained. This malfunction vividly demonstrates the need for good vidicon high-voltage regulation.

c. Tape Recorder

The performance of the camera system No. 2 tape recorder was very good and was very similar to the performance of the tape recorder in camera system No. 1. In most of the pictures examined, no flutter or wow was discernible. In the small percentage containing flutter, the effect was barely discernible. There was no evidence of malfunction in any of the pictures. As with tape recorder No. 1, tape dropouts occurred frequently on frame 32 of remote sequences. This was apparently caused in the same way as the dropouts observed in the camera system No. 1 remote pictures, as a result of a shavings of mylar material which became embedded in the recording side of the tape at the position of the first recorded frame.

d. TV Transmitter

The camera system No. 2 TV transmitter performed normally throughout the evaluation period, providing strong signals to the CDA stations. There was no evidence of malfunction or degradation in the transmitting or modulating circuits.

4. Ground Station Components

The ground station components of the TV picture subsystem performed satisfactorily, requiring only routine adjustments and replacements during the 30-month period. Detailed accounts of performance of each of the ground stations are given in Section XIV of this report.

VI. INSTRUMENTATION CONTROL SUBSYSTEM

A. FUNCTION

The instrumentation control subsyst em consists of the satellite and ground station components required to allow control of satellite operations by the Command and Data Acquisition (CDA) ground stations. The ground station components of the control subsystem consist basically of programming units for selecting coded commands for specific satellite functions, and communications equipment for modulation and transmission of the command messages to the satellite. Because of the limited duration of each communications contact between a ground station and the satellite, and because part of this time is consumed in receiving data from the satellite, highly accurate timing equipment is also necessary so that the command messages can be selected in advance of a contact and then generated and transmitted in sequence at high speed, and at preset alarm times. Several types of command coding are used, each consisting of some form of control function identification (direct pictures, playback, spin-up, etc.) plus the action to be taken. The commands range from discrete commands, to which a satellite subsystem makes an immediate, single response (e.g., fire spin-up rockets), to programs that are stored by the satellite subsystem and used to control delay timing and picture taking while the satellite is beyond communications range of a ground station. The ground station equipment also includes components for automatic satellite tracking and for programmed satellite tracking during the satellite-to-ground radio contact.

The satellite contains communications receiving equipment to receive and demodulate the commands, control circuits which separate the commands and initiate the individual command functions, and storage and counting (clock) subsystem which store remote programs and synchronize and control the sequence of operations of the TV cameras, tape recorders, and transmitters. A command address function was added to the TIROS VII satellite control subsystem to prevent the satellite from responding to transmissions intended for other TIROS satellites or to any transmissions other than valid TIROS VII commands transmitted by the CDA stations. (Both TIROS V and VI were still being commanded and interrogated at the time of the TIROS VII launch.) The address function prevents the TIROS VII control circuits from responding to any command except those that are preceded by the TIROS VII coded address.

The satellite functions that are controlled by ground command are as follows:

(1) Operation of the TV camera systems in either the direct or remote mode of operation, including picture interval, and, in the case of direct operation, the duration of the picture sequence.

(2) Readout (playback) of stored TV and sun-angle data.

(3) Readout (playback) of stored infrared subsystem data (including ETP data).

(4) Telemetry readout.

(5) Beacon "kill" and turn-on.

(6) Magnetic attitude control.

(7) Firing of spin-up rockets.

(8) Backup of de-spin mechanism and precession damper operation (both normally initiated automatically at separation from the third-stage rocket).

The ground-station components of the instrumentation control subsystem include command programmers, control-tone generators, remote-picture time-set units, clock-set pulse demodulators, a program selector and power control, a command transmitter, antenna programmer, a WWV receiver, a master clock, an alarm unit, and power supplies. The satellite components of the subsystem include two command receivers, two camera-control units, an auxiliary-control unit, two timing and sequencing (clock) units, a magnetic attitude control circuit, a rocket-firing control circuit, a beacon turn-off control circuit, and two one-year timers. Details concerning operation of the components, the modes of operation, the program sequences, and the command functions are described in detail in the TIROS VII final report.

B. PERFORMANCE EVALUATION

1. General

The performance of the instrumentation control subsystem on the TIROS VII satellite was in general very good. The command address unit, used for the first time on TIROS VII, virtually eliminated responses to spurious commands from external sources, a problem that had been experienced with increasing frequency on the previous TIROS satellites. Evaluation tests demonstrated that command sensitivity and the command antenna pattern were normal. The control circuits responded to all commands; however, there were instances of late clock alarm. Detailed investigations were made in connection with this problem. Several corrective measures were taken on the basis of these investigations with very good results and a considerable improvement in clocksetting accuracy was achieved. For example, during a four-month period from August 1963 to November 1963, clocksetting accuracy varied from 46 to 68 percent. During the four-month period from September 1964 to December 1964, clock-setting accuracy varied from 56 to 85 percent and the lower value was obtained during December when ground difficulties caused 13 of the 43 instances of inaccurate clock-setting. Not counting the month of December, the low for this period was 72.5 percent (November). During 1965, the accuracy of clock-setting remained well above 80 percent.

2. Command Receiver Sensitivity Tests

An evaluation of satellite receiver sensitivity was made as a first step in the investigation of the late clock alarms. Test transmissions were conducted at reduced RF power from the AED ground station during orbits 194 and 209 in order to determine the minimum power required to obtain reliable satellite responses. Two transmitters were used in the tests, one adjusted for an RF output power of 20 watts and the other for an output power of 45 watts. (The two transmitters at each of the primary command and data acquisition stations have output powers of 200 watts and 2 kilowatts.) Both transmitters were tuned to produce a clean command tone at approximately 90 percent modulation.

On orbit 194, the TIROS VII command address was transmitted using the 20-watt transmitter. No response was received and, after 60 seconds, the address was again transmitted, this time using the 45-watt transmitter. The satellite responded normally to the second transmission. The direct-picture command was transmitted continuously by the ground station and received continuously by the satellite throughout the remainder of the pass, as indicated by the absence of unprogrammed direct pictures.* At the end of the pass, when the antenna elevation angle had decreased to two degrees (a slant range in excess of 1600 miles), an emergency telemetry command was transmitted to the satellite using the 45-watt transmitter. The satellite responded with a normal telemetry readout, indicating proper operation of the receiving circuits. The TV transmission from the satellite was still being received as the satellite passed over the horizon.

On orbit 209, the satellite responded normally to the first command address transmitted by the 20-watt transmitter. The command tone transmitted to the satellite was received continuously (as indicated by the absence of unprogrammed pictures) and continued to be received until the TV transmitter was turned off near the end of the pass. At an antenna angle of approximately 5 degrees (a slant range of approximately 1500 miles), the emergency telemetry command was transmitted and the satellite responded as programmed.

In making an estimate of the command sensitivity of the RF circuits of the TIROS VII satellite, the data from pass 209 was used because it clearly demonstrated that the receiving circuits were performing normally at maximum slant range when the 20-watt transmitter was used to transmit the commands. In making this initial estimate of command sensitivity, the "look angle" of the satellite's command antenna was assumed to be the least favorable, since this assumption would yield a minimum value for command sensitivity; any change in the look angle could only result in an improvement in the strength of the signal received by the satellite.

At the primary CDA stations, 200-watt command transmitters are employed, rather than the 20-watt transmitter power used for the sensitivity test; also, the gain of the

*Direct pictures are taken when the satellite senses a momentary drop-out in the direct-picture command.

command antennas at the CDA stations is 3 db greater than that of the AED antenna used for the test. Thus, the level of the command signals transmitted from the CDA stations is 13 db greater than that of the signals transmitted during the test and, since the satellite responded normally during the test, it was apparent that, even under worst-case conditions, the system margin for the CDA-to-satellite command link was at least 13 db. With this level of system margin, it was also apparent that the RF equipment in the satellite was functioning normally and that the sensitivity of the command receivers was within a normal range.

To obtain a more exact estimate of receiver sensitivity and command margin, satellite attitude data was used to calculate satellite look angles during orbit 209. The calculated look angles together with the TIROS VII command antenna pattern and the record of slant range between ground station and satellite antennas provided the data necessary for calculating the signal levels at the input terminals of the satellite's command receiver. Using these calculations, and making allowances for possible error in the data, a minimum of three db of additional margin was verified, for a total margin of no less than 16 db. With a verified margin of this magnitude, the clock-setting problem cannot be ascribed to inadequate command sensitivity of the satellite's RF circuits.

3. Investigative Programming Tests

After adequate sensitivity of the TIROS VII command receiver had been verified, consideration was given to investigative programming techniques that could be used in interrogating the satellite in order to gain more insight into the nature of the clock-setting difficulty. In conjunction with these programming tests, data acquired previously during regular programming of the satellite was reviewed to uncover any related operational anomalies that might be apparent in the recorded data.

The programming tests were conducted at the AED ground station during orbits 423, 424, and 437. These tests were directed primarily toward checking a suspected relationship between clock-setting accuracy and the initiation of playback of data from the infrared subsystem. In the special program used for these tests, the playback of IR data takes place at the beginning of the period in which the clocks are set. At the initiation of the IR playback the IR transmitter turns on. This occurs during the time when the first clock to be set is receiving the set pulses. The duration of each pulse is relatively short and a momentary interruption in normal operation could result in the loss of many pulses. Each lost pulse results in a two-second error in clock alarm time.

An emergency playback mode of operation was programmed on orbits 423, 424, and 437.* A variation of this program was used during orbit 423 in which system No. 2

*The 1N-2N emergency playback sequence was programmed. In this program, the playback command tone is transmitted for a longer period than when the playback sequence is preceded by direct camera operation; the purpose of this program is to provide warm-up time for the TV transmitters at the beginning of the playback sequence, for use when a ground station malfunction prevents transmitter warmup in the direct picture mode.

was kept in the playback mode (by keeping the manual pushbutton depressed) until the IR playback had ended. The clock set command to system No. 2 was then transmitted. As a result of this programming, system No. 1 did not alarm at the programmed time, while system No. 2 alarmed as programmed. On orbit 424, this program was repeated but with the modulation of the command to system No. 2 reduced to 70 percent. This was an attempt to establish more positively that inaccurate clock setting was connected with IR playback and at the same time to obtain evidence of system No. 2 control circuit sensitivity to the demodulated clock set commands from the receiver. Neither clock alarmed on time; however, since clock No. 2 did alarm, the sensitivity of the clock No. 2 control circuit was deemed adequate for receiving commands modulated at normal levels.

The review of the results of previous clock setting programs was conducted at this time. It was found, as a general rule, that when only one of the clocks was set during an orbit, the clock alarmed late. When both clocks were set, the one set last usually alarmed accurately while the first alarmed late. The evidence obtained from orbits 423 and 424 and from the review of past programs indicated that a correlation did exist between the clock inaccuracies and some event occurring while the first clock was being set, very possibly the initiation of IR playback. To further test this possible correlation, a manual program was used during orbit 437. Clock No. 1 was set after the IR subsystem had started transmitting and the telemetry readout had been completed (thus avoiding the power supply transients that accompany these events). Clock No. 2 was set after IR playback had been completed. Both clocks alarmed on time, once again showing an apparent correlation between clock setting accuracy and IR initiation. A specific implication is that the power supply transients occurring when the IR transmitter turns on or when the telemetry switch advances might prevent the accurate reception of clock-set pulses during these periods.

The program used at AED during orbit 437 was also used by the Wallops Island station during interrogations on July 22 and 23, 1963 and resulted in a significant increase in the number of accurate clock alarms.

Although no specific conclusion regarding the clock set problem could be reached as a result of these special test programs, it was apparent that the clocks should not be set during periods of high current drain, such as telemetry switching or IR playback initiation.

4. Auroral Effects at the Alaska Ground Station

a. General

The aurora borealis (northern lights) is a frequently observed phenomenon at the Alaska ground station and is known to increase the path attenuation of radio waves. In meetings with AED representatives, University of Alaska personnel have stated that difficulty with radio interference resulting from auroral phenomena should be expected about 20 percent of the time at the location of the Alaska station. The mechanism by which the auroral effect causes attenuation of radio waves and the amount of

attenuation the results from aurora are not completely understood, although it is suspected that the attenuation varies with the temperature of the ionosphere, the prevailing geomagnetic activity, and the 11-year sun-spot cycle. It is known that the aurora, in addition to causing attenuation of radio waves, causes an increase in atmospheric noise and that both effects decrease with decreasing transmitting frequency.

The effects of the aurora borealis on the command link of the TIROS VII spacecraft were given attention in this investigation because the incidence of inaccurate clock alarms was greater on orbits programmed by the Alaska ground station than on orbits programmed by either of the other TIROS ground stations. Two passes were observed and studied in detail at the Alaska station, in order to gain more insight into the nature and characteristics of the effect of the aurora borealis on transmissions to and from the satellite. These passes took place during orbits 2705 and 2718. Signal losses in excess of the command receiver margin were observed on one of the passes, indicating that the magnitude of the effect was large and must be taken into account in any instance of inaccurate clock setting by the Alaska ground station.

b. Orbit 2705 (December 19, 1963)

A tracing of the Sanborn recording of the TV receiver agc signal made during orbit 2705 at the Alaska ground station is shown in Figure VI-1. Both the vertical and horizontal components of the signal are shown. At 09:40.36 Z the signal levels of both components began to decrease rapidly and continued to decrease until they were just above the agc noise level. These "fades" lasted until approximately 09:40.52, when both components again were of normal strength and continued to be normal until the TV transmitter turned off at 09:41.26. At the time of the fades, antenna elevation was approximately 30 degrees. The noise level in each of the IR agc channels increased slightly. (The IR transmitter had not yet been turned on.) The antenna tracking subsystem lost control of the antenna. (The low beacon signal, at 136.23 Mc, is used for tracking, and thus any failure or malfunction in the TV receiving system could not account for the loss of antenna control.) Control of the antenna was transferred to the antenna programmer so that tracking of the satellite could continue. Maximum elevation (minimum slant range) was reached at 09:42.00 Z after the TV transmitter had turned off; however, maximum signal strength in the IR receiver for the vertical component did not occur until 09:43.01 Z. This example of fading was identified by the antenna site operator as typical of the disturbances caused by atmospheric conditions that have been observed on numerous occasions at the Alaska station.

Figure VI-2 shows the orbit subtrack path of the satellite on orbit 2705 with respect to the Alaska ground station (ULASKA). Also shown on the diagram is the location of Clear, Alaska, site of a BMEWS radar installation. During the period of fading of the satellite signals, the ground station antenna was pointed approximately in the direction

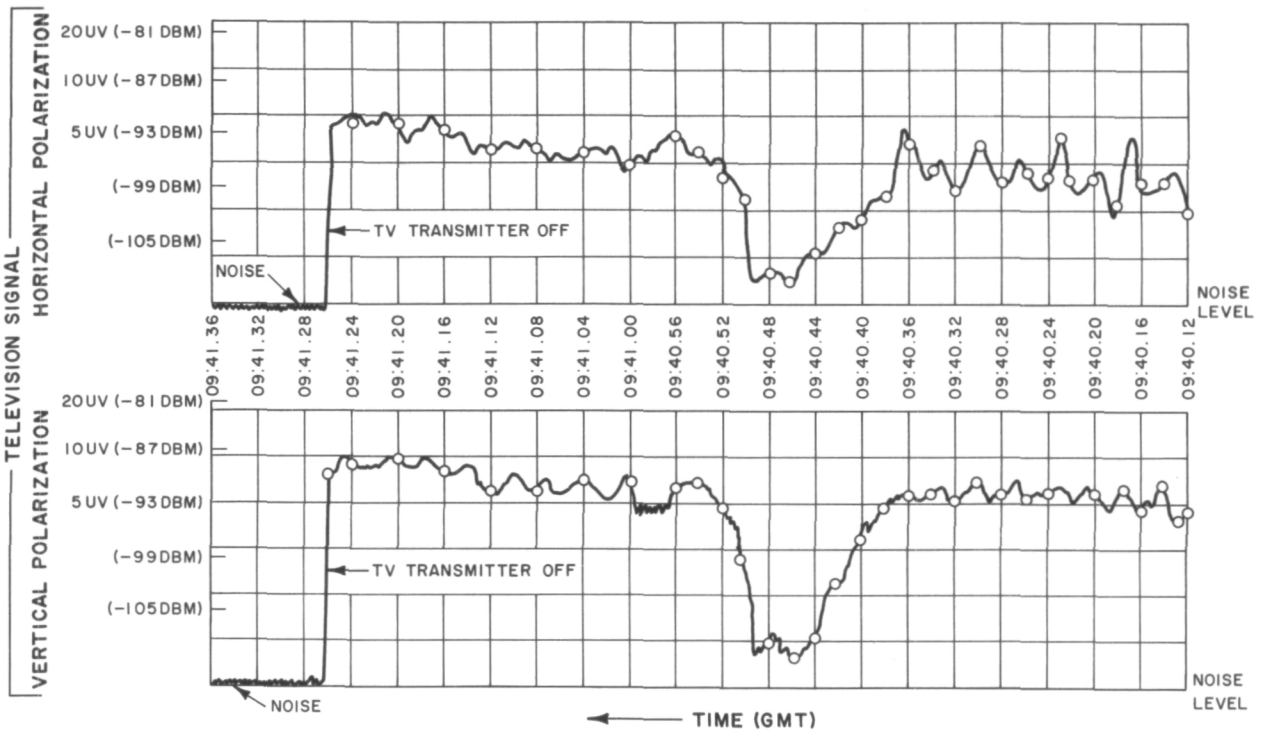


Figure VI-1. Recordings of TV AGC Signals on Orbit 2705 (Alaska)

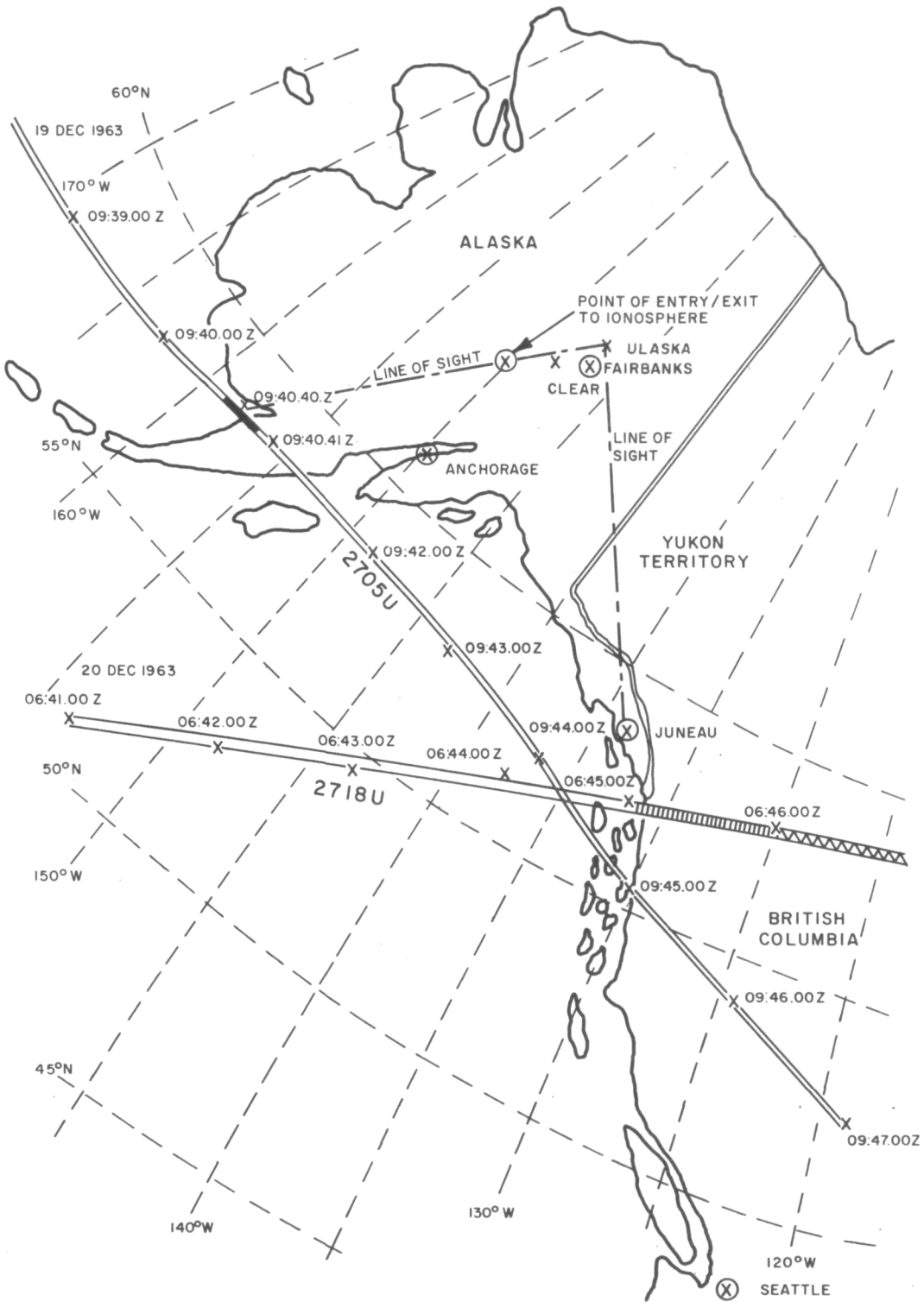


Figure VI-2. Orbital Subtracks on Orbits 2705 and 2718

of the powerful BMEWS radar transmitter. However it is believed that the TIROS receivers were not blocked by radar transmission from Clear, for two reasons:

(1) If the TIROS receivers were being blocked by the BMEWS radar signal, an increase rather than a decrease in agc voltage would have been observed.

(2) The hills around the ULASKA site shield the receivers from line-of-site reception from Clear.

The fading on this orbit is therefore believed to be the result of some atmospheric effect, perhaps aggravated by stimulation of the ionosphere by a radar transmission from the BMEWS site.

c. Orbit 2718 (December 20, 1963)

During orbit 2718 the satellite was tracked by the APT helix antenna system as well as by the TIROS 85-foot dish antenna system, thus providing two independent means of tracking from two different locations using independent control systems frequencies. (The TIROS antenna tracked the 136.23 Mc beacon signal and the APT antenna tracked the 136.92 Mc beacon signal.) The two systems provided, in effect, double diversity reception (space and frequency) of the satellite's transmissions.

The orbit sub-track during orbit 2718 is shown in Figure VI-2. Plots of the agc voltage and agc detector output voltage, taken from observed meter readings, are shown in Figure VI-3. Also shown is a sketch of the recording of agc voltage in the 136.23 Mc receiver made on the Sanborn recorder in the Data Acquisition Facility equipment.

Before 06:45.00 Z, the agc level was fairly constant with slight variations, probably as the result of the varying satellite antenna pattern as the satellite rotated. At 06:45.00 Z, the agc voltage started to fluctuate erratically, with momentary excursions below the noise level. These excursions, indicating fades of 30 db or more, were so brief that the antenna system continued tracking automatically. Finally the signal was lost as the satellite went below the local horizon.

Because the 85-foot dish antenna system and the APT helix antenna system are completely independent systems and yet encountered the same erratic fluctuations in the signals they were tracking, it is very unlikely that this problem could have been caused by abnormal performance of the ground station receiving or antenna control equipment. The command transmitter had turned off before the fluctuations began and could not have caused the problem. Two different beacon signals were being tracked; it is not likely that both beacons became erratic at the same time. Nor can such random fluctuations be attributed to the rotating radiation pattern of the spacecraft antenna. An erratic condition of the satellite power supply could have affected both beacon transmitters; however, there were no other indications of a power supply problem. The power supply voltage telemetered on orbit 2718 was 27.2 volts.

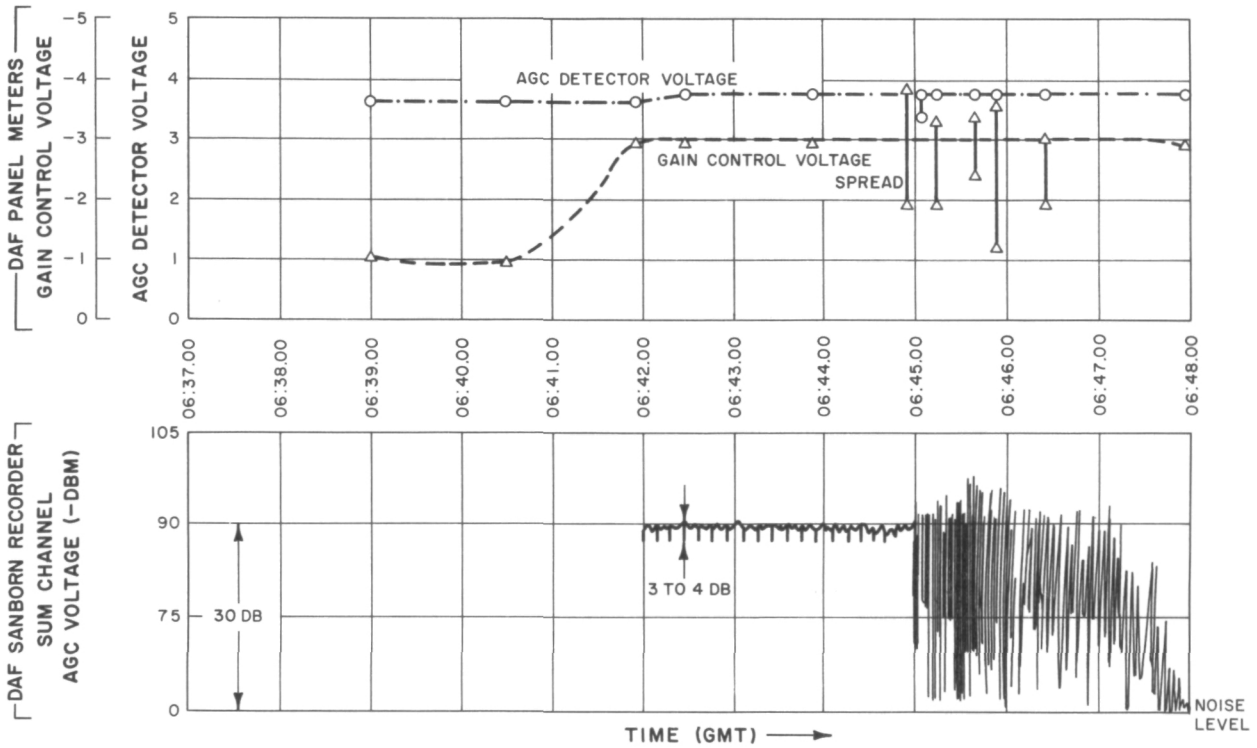


Figure VI-3. Plots of AGC Detector Voltage and AGC Sum Channel Voltage on Orbit 2718 (Alaska)

The most likely source of the abnormal performance observed on orbit 2718 was an ionospheric disturbance that interfered with the signals passing from the satellite to the Alaska ground station. Sufficient data on the condition of the ionosphere during the pass (in particular, the electron density) is not available to determine if the 30-db fluctuations observed are consistent with previously measured ionospheric absorption losses. The indicated losses do, however, appear to be large for the frequencies involved,* although precise data for the time, location, and particular conditions are not available.

5. Antenna Radiation Angle Measurements

Satellite antenna radiation angle data for three groups of orbits was compared to obtain an indication of any relationship between the radiation angle and the clock setting problem. The first group (Group A) consisted of orbits on which the clock alarm did not occur at the programmed time. The timing inaccuracies in this group varied from 6 minutes and 20 seconds in advance of the programmed time to 38 minutes after the programmed time. Group B consisted of orbits during which the TV transmission from satellite to ground station dropped out during the contact or difficulty was encountered in commanding the satellite. Group C was a control group, consisting of orbits on which no difficulties were encountered.

For each orbit in each group, the satellite antenna radiation angle (angle between the satellite spin axis and the line-of-sight from the satellite to the ground station) was determined for the beginning and end of the period in which commands were transmitted to the satellite. Polar plots of the radiation angles for each orbit and of the dipole antenna pattern of the command receiving antenna are shown in Figure VI-4. It is apparent that there were no consistent differences between the radiation angles of the three groups. Even though the angles for groups A and B do extend over a slightly greater range than those of the control group, the signal loss is not significant in a system having a margin of at least 16 db above the system threshold. No correlation can be made between the antenna pattern of the satellite and the clock setting problem.

6. Check on Clock-Set Transmissions to the Satellite

Command transmissions from the Wallops Island ground station were monitored during the period from January 10 to January 16, 1964 in order to determine if any deficiency existed in the waveshape of the clock-set pulses transmitted to the satellite. For this check, a TIROS command receiving antenna, a calibrated TIROS receiver, and test equipment were connected as shown in Figure VI-5 so that transmissions from the Wallops Island station to the satellite could be received and recorded. Polaroid

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*See "Geomagnetic Control of Satellite Scintillations", Journal of Geophysical Research, Volume 68, No. 10, 3159-3168, May 15, 1963. (Variations of 3 db at frequencies of 54 and 150 Mc are given for a Massachusetts observatory.)

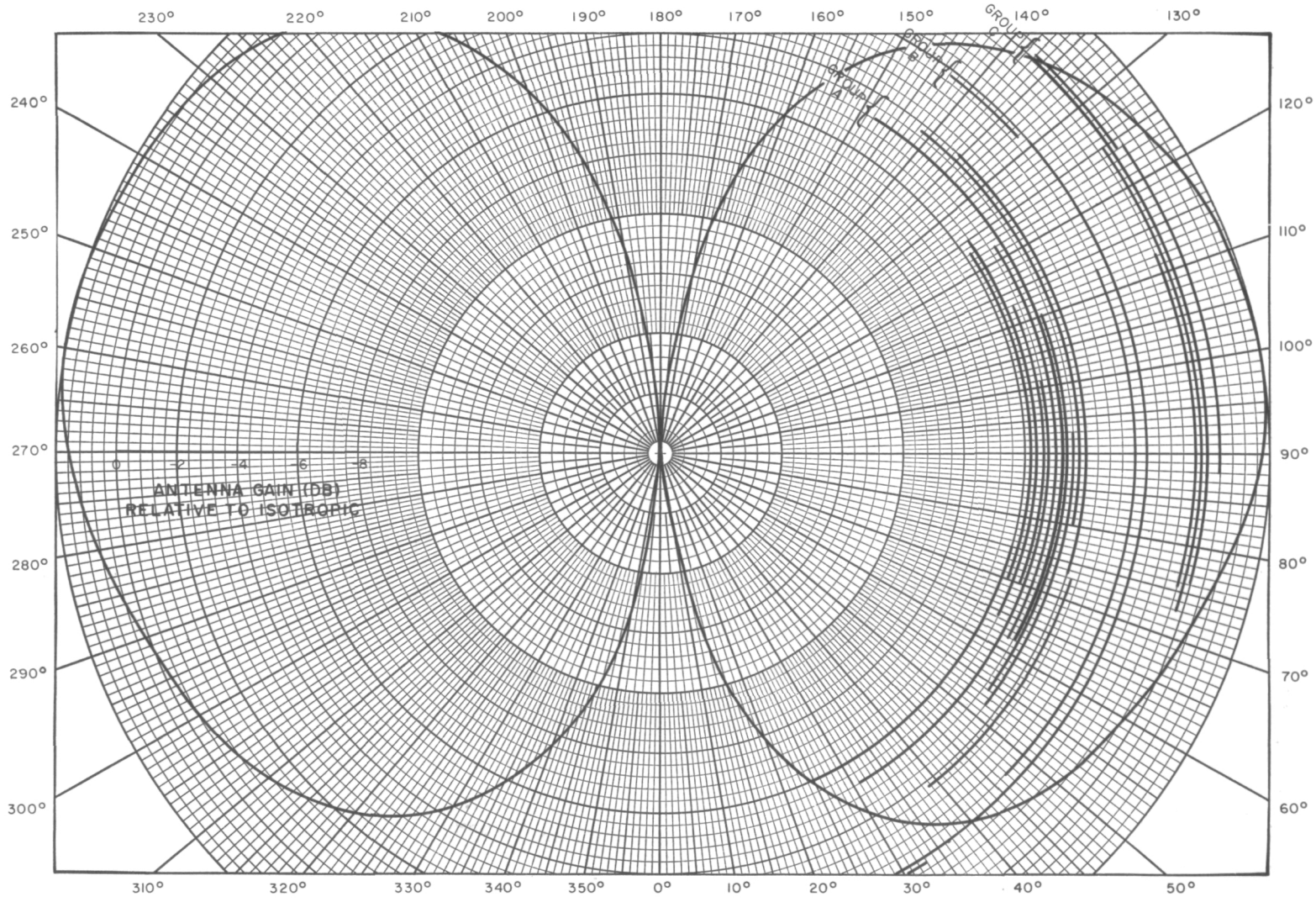
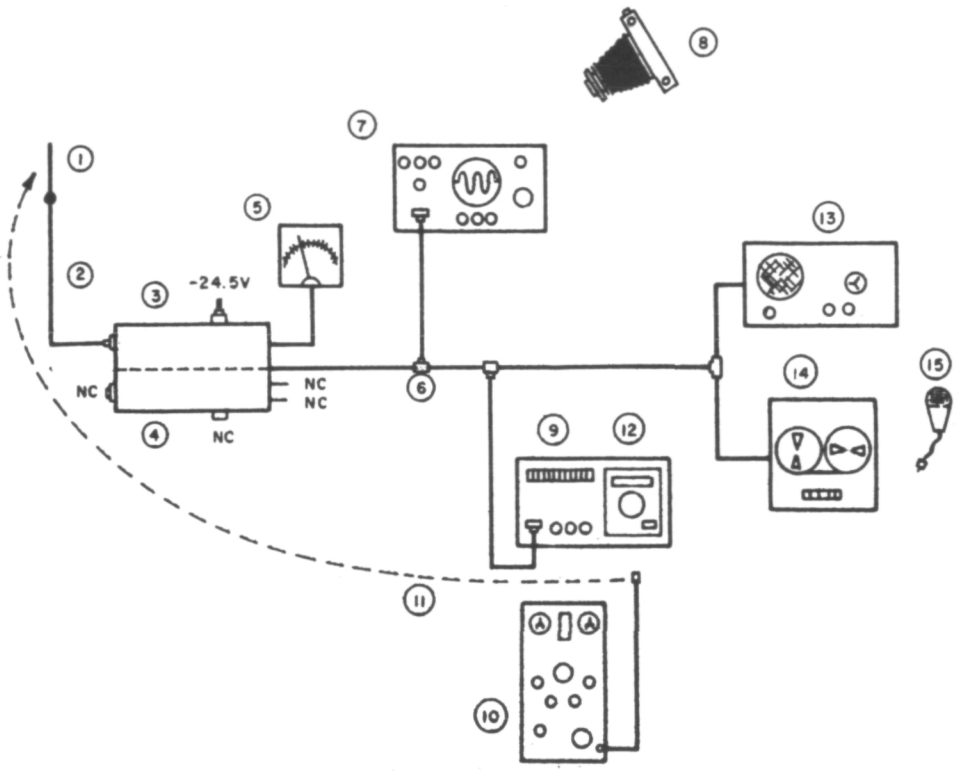


Figure VI-4. Results of Command Antenna Radiation Angle Measurements



1. TIROS COMMAND ANTENNA (12 FEET ABOVE GROUND)
2. COAXIAL CABLE
3. TIROS COMMAND RECEIVER NO. 1 (USED)
4. TIROS COMMAND RECEIVER NO. 2 (NOT USED)
5. AGC METER
6. COAXIAL CABLE
7. TEKTRONIX RM504 OSCILLOSCOPE
8. CAMERA FOR OSCILLOSCOPE
9. HEWLETT-PACKARD 5243L COUNTER
10. HEWLETT-PACKARD 608D RF OSCILLATOR
11. LEAKAGE SIGNAL FROM HP609D TO ZERO-BEAT WITH WALACQ CARRIER
12. HEWLETT-PACKARD 5253A RF PLUG IN UNIT (TO MEASURE 609D SIGNAL WHEN IT WAS ZERO-BEAT WITH WALACQ)
13. MAGNECORD PT6-J AUDIO AMPLIFIER AND SPEAKER
14. RCA TAPE RECORDER
15. MICROPHONE FOR RECORDING VOICE ANNOUNCEMENT ON THE TAPE

Figure VI-5. Equipment Set-Up Used to Monitor Clock-Set Command Transmissions from Wallops Island

pictures were made of the oscilloscope presentation of the clock set pulses transmitted during a number of orbits. The pictures revealed a wide variety of pulse shapes, some of which are shown in Figure VI-6.b and c. (Figure VI-6.a shows the normal pulse shape.)

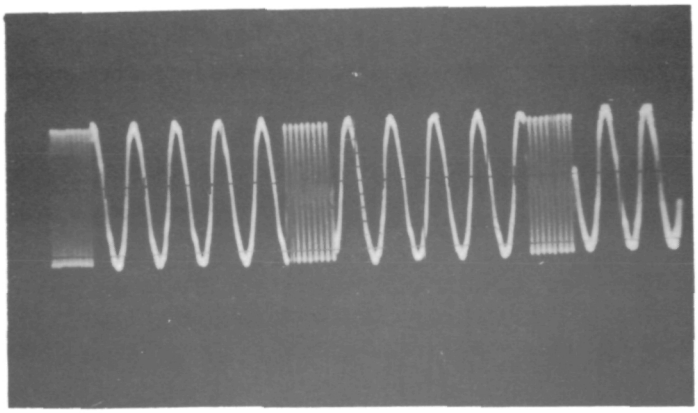
The satellite clocks are set for remote alarm by transmitting a group of "set pulses" to the satellite. Each pulse consists of an audio frequency sine wave. The tone bursts are combined with the playback command tone and the clocks are set during the playback of TV picture data. The PB tone frequency identifies the clock setting circuit for which the pulses are intended. A maximum of 9000 tone bursts can be sent to each clock; each tone burst that is accepted by the clock set circuit in the satellite is stored and results in a two-second delay in alarm time. Thus the maximum delay is 18,000 seconds or 5 hours.

The output of the satellite receiver is a composite of the audio bursts, at the clock-set tone frequency, interspersed with the playback tone. An audio filter separates the two signals and the set-clock tone bursts are applied to a threshold circuit. The portions of the bursts that exceed the threshold are detected and integrated to form a pulse. Because of the integration process, there is a delay between the time when the tone burst first exceeds the threshold and the time when the leading edge of the integrated pulse occurs. This delay is dependent on the amplitude of the tone burst. If the tone burst amplitude should decrease to less than a certain minimum value, then the integration time would exceed the tone burst duration, and no output pulse would be produced.

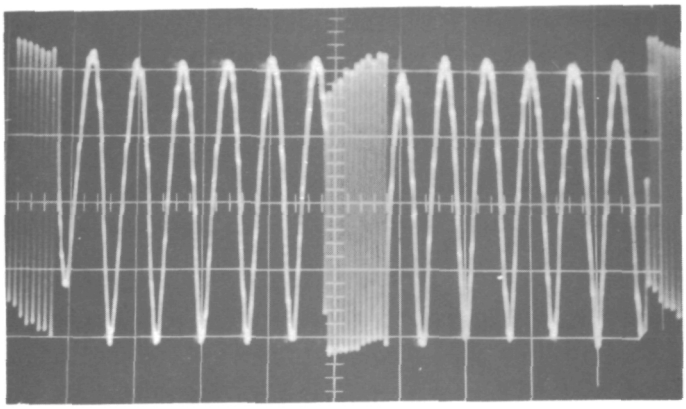
Any decrease in tone burst amplitude lessens the probability of a set-clock pulse being produced. A decrease in tone burst duration (above the threshold), of course, also reduces the chances of a set-clock pulse being produced.

When an integrated pulse is produced, it triggers a monostable multivibrator which produces a clock-set pulse of standard amplitude and duration required for setting a single (two-second) count into the satellite clock. The amplitude and duration thresholds in the detection circuits prevent noise or spurious signals from setting unprogrammed counts into the satellite clocks. Because of these thresholds, any degradation of signal level, modulation, or waveshape can render valid clock-set pulses indistinguishable from spurious signals, whereupon the valid pulses will be rejected by the detection circuit.

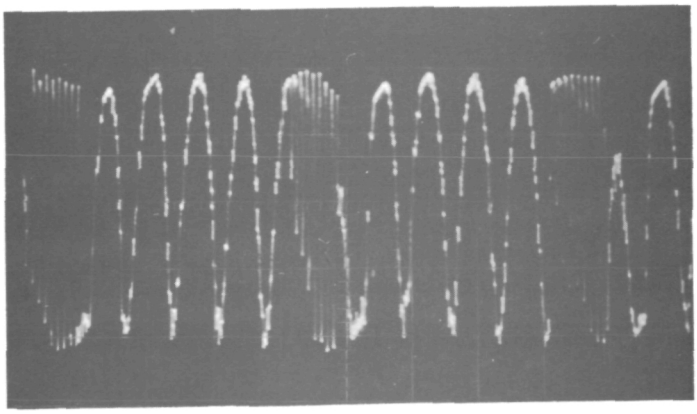
The pulses monitored in the Wallops Island transmissions (Figure VI-6) revealed a variety of deficiencies and variations from pulse to pulse. The normal tone-burst pulse is shown in Figure VI-6a. The pulse shapes shown in Figures VI-6.b and VI-6.c begin below the threshold (the negative-going portion is detected) and, even though they eventually rise above the threshold, the durations above the threshold may not be sufficient to exceed the integration delay time. The pulse shape shown in Figure VI-6.b varies from pulse to pulse so that if one pulse decreases in amplitude, the succeeding pulse increases in amplitude. Furthermore, the pulses shift with respect to the base line. This could result in the loss of alternate pulses.



(a)



(b)



(c)

Figure VI-6. Normal Clock-Set Pulse Waveshape (Top) and Waveshapes Monitored at Wallops Island CDA Station, January 10 to 16, 1964

During the period in which the clock-set transmissions were monitored, the amplitude and positioning of the tone bursts were adjusted once and sometimes twice each day. Some drift was found to exist in the gating circuits of the control tone generator in which the tone bursts were formed.

A series of transmissions was carried out between January 24 and February 4, 1964, at the Wallops Island ground station, to test the effect of an increase in the width of the set pulses. Both operating satellites were commanded (VII and VIII). The wider pulses were used not only to compensate for the deficiencies in pulse shape observed in the previous tests but also to overcome any increase in the pulse integration time in the satellite's clock set detection circuit. The results of these transmissions were an increase in clock alarm accuracy in all but system No. 1 of TIROS VII. The playback transmission from the satellite tended to drop out during the period in which the clock-set pulses were being transmitted to system No. 1. The frequency of occurrence of drop out of the system No. 1 playback transmission was observed to increase as the pulses were made wider. This showed conclusively that an anomaly existed in the "off-delay" control circuit for system No. 1, since, under normal conditions, an interruption in the playback tone of at least 26 seconds must occur before playback transmission can drop out. The maximum number of pulses sent to the clock (except in the case of emergency programming techniques such as oversetting the clock) is 9000; the total transmission time is 70 seconds which means that under normal conditions, the maximum time between pulses is far less than one second. Apparently, however, the increased width of the clock set pulses (and hence the decreased intervals in which the playback tone is transmitted) prevented recognition of the playback tone. Therefore a second change in the clock-set pulse format (in addition to the increase in pulse duration) was tested. This programming technique resulted in an immediate and marked improvement in clock-set accuracy without deleteriously affecting playback performance. The technique was put in use at all of the CDA ground stations in March 1964 and has resulted in greatly increased clock setting accuracy.

VII. NASA INFRARED SUBSYSTEM AND ETP

A. FUNCTION

The NASA infrared (IR) "heat-mapping" subsystem included on the TIROS VII satellite is similar in function to the NASA IR subsystems installed on the TIROS II through V satellites (an accelerated launch schedule prevented the inclusion of the IR subsystem on TIROS VI). However, the TIROS VII IR subsystem differs in instrumentation from the previous IR subsystems in that the new tape recording unit designed for the Nimbus satellite was installed for experimental use on TIROS VII. In addition, an electron temperature probe (ETP) experiment was added to measure the temperature and density of free electrons in the satellite's orbital environment. With the exception of the ETP power control, which was designed by AED, the infrared subsystem and the ETP experiment were furnished by NASA. The IR subsystem was installed, tested, and calibrated by AED.

The IR "heat-mapping" components consist of infrared sensing devices to measure heat radiation and reflection from the earth and its lower atmosphere, magnetic tape recording equipment to store the IR data, and control and transmitting equipment to play back and transmit the data to the ground stations. During each orbit, the infrared and electron-temperature data are recorded continuously on IR tape for up to a maximum of 100 minutes. Upon interrogation, the data are played back and transmitted to a CDA station at an accelerated rate such that the 100-minute recording is played back in 3 minutes and 20 seconds.

IR playback operation is initiated when an "interrogate" pulse is received from the TV subsystem in the satellite. This pulse is generated at the beginning of each direct-camera sequence and each TV playback sequence.

The NASA-furnished portion of the IR subsystem consists of the following components: (1) a scanning, five-channel radiometer (FCR); (2) a pair of omnidirectional radiometers; (3) a continuous-loop magnetic tape recorder; (4) an FM transmitter; (5) signal electronics circuits; (6) the ETP; and (7) the ETP control unit. The data signals, including the outputs of the radiometers and the ETP, as well as telemetry data and three time-reference pulses (a satellite revolution-count pulse, the TV camera shutter pulse, and the TV recorder end-of-tape pulse) are multiplexed, employing a combination of time-sharing and subcarrier frequency division, to produce a composite baseband. The baseband signal is recorded on magnetic tape at all times except during the first three and one-third minutes of a satellite interrogation, when the tape recorder is played back at high speed and the data is transmitted to the ground. The IR transmissions are fed to the satellite's matching and coupling network and radiated simultaneously with

TV and telemetry transmissions during the first part of the ground station contact. In order to avoid the loss of real-time IR and ETP data during the playback of the recorded IR data, the outputs of the IR and ETP sensors bypass the tape recorder and are combined with the playback data for transmission to the ground.

The IR sensing devices measure earth radiations and reflections in the electromagnetic spectrum from infrared to ultraviolet. The FCR unit consists of a group of five thermistor-flake bolometers, each of which is equipped with a filter to limit its sensitivity to a specific portion of the electromagnetic spectrum between 0.2 and 30 microns. These sensors are designed to alternately view the earth (through an opening in the satellite baseplate) and to view space (through an opening in a side wall of the satellite hat). The space measurement provides a reference for the other measurements. The view angles of both the upward and downward fields-of-view are 45 degrees with respect to the baseplate. A system of rotating prisms and five chopping wheels serves to alternate the field-of-view between space and earth.

The University of Wisconsin omnidirectional readiometer consists of two pairs of black and white infrared sensors, which are mounted at the ends of extension arms that project in diametrically opposite directions from beneath, and approximately in the plane of, the satellite baseplate. The arms are spring-loaded and self-extending, being actuated by operation of the de-spin mechanism shortly after separation of the satellite and third-stage rocket. The black sensor is designed to measure the following three parameters: (1) radiation from the sun, (2) reflected short-wavelength radiation from the earth, and (3) long-wavelength (infrared) radiation from the earth. The white sensor measures the long-wavelength reradiation from the earth. The combined measurements from both sensors encompass the earth's thermal radiation and reflection characteristics. The omnidirectional infrared experiment on TIROS VII is very similar to the one which was developed for use on the Explorer VII satellite and has been used on TIROS satellites II through V.

The ETP consists of a whip-like probe extending radially from the baseplate and an electronics unit which provided an electrical analog of the density and temperature of the free electrons in the orbital environment.

B. PERFORMANCE EVALUATION

The detailed evaluation of the infrared subsystem, including the electron temperature probe, is being performed by NASA and the results will be reported in a separate NASA publication. In general, the IR subsystem performed very well, returning large quantities of useful data. However, several problems were encountered, including the disabling of University of Wisconsin (omnidirectional IR) experiment by a malfunction of the IR telemetry switch, a variation from normal playback time of the IR tape recorder, and a capacitor problem in the electron temperature probe. Programming of IR readouts was curtailed on some occasions when the satellite was experiencing unfavorable gamma angles. However, during December 1964, after 18 months of

orbital operation, the IR subsystem was performing normally and was being programmed on an average of three to six orbits per day.

During 1965, the IR subsystem continued to perform. Except for the February 19, when the torquing maneuver* on TIROS VII was performed, the IR subsystem was programmed on an average of four times each day and returned large quantities of useful data. The detailed performance evaluation of this subsystem was reported by NASA in a separate document.

*Refer to Section IX for a description of this maneuver.

VIII. TELEMETRY AND TRACKING SUBSYSTEM

A. FUNCTION

The TIROS VII satellite telemetry and tracking subsystem consists of two beacon transmitters and two identical 40-point telemetry circuits. The ground station telemetry equipment consists of diversity-connected beacon receivers and telemetry demodulating and recording equipment. As on the TIROS VI satellite, the TIROS VII satellite is equipped with two 1-year timers, each of which was designed to turn off both beacon transmitters at the end of one year's operation in orbit. The 50-milliwatt beacon transmitters operate continuously throughout each orbit (unless temporarily turned off by the beacon "kill" command). During the greater portion of the orbit, while the satellite is not in contact with the ground stations, the beacon transmitters are amplitude modulated by the attitude data. This permits the stations of the NASA Minitrack network to track the satellite to obtain position information so that ephemeris data can be prepared for the CDA stations. When the satellite is interrogated by a ground station, either in the playback or in the direct-picture mode, a telemetry readout is automatically initiated, displacing the attitude data for a period of 32 seconds. The 39 telemetry points are sampled and the telemetry voltages, in turn, are frequency modulated on a subcarrier. The subcarrier is amplitude modulated on the beacon carrier. A telemetry readout can also be initiated by an emergency telemetry command transmitted by the ground station.

Each telemetry circuit consists of a 40-position (35 operational parameter sampling positions, 4 calibration sampling positions, and a "home" position) electromechanical selector switch; a voltage-controlled subcarrier oscillator (SCO), operating at a center frequency of 300 cps; and various temperature sensor and voltage and current sampling networks.

When a telemetry-sampling cycle is initiated, the selector switch steps through its 40 positions, remaining at each of 39 data-sampling positions for 0.8 second, and stopping at the 40th, or home, position. At each sampling point, the voltage generated by the sensing device is applied through the sampling switch to the SCO, causing a proportional shift in the SCO frequency. The upper and lower limits of the voltages from the sensing devices are +2.5 volts d-c and -2.5 volts d-c, corresponding to SCO frequency shifts of +100 and -100 cycles per second (for an overall SCO output frequency range of 1200 to 1400 cps). The output of the SCO is used to amplitude-modulate its associated beacon transmitter for transmission of the telemetry data to the interrogating ground station. The telemetered parameters and their assigned telemetry channels are given in Table VIII-1.

TABLE VIII-1. TELEMETERED PARAMETERS: TIROS VII

Telemetry Switch Position No.	Parameter (136.23-Mc Beacon Channel B)	Parameter (136.92 Mc Beacon Channel A)
1	Calibration: Zero Volts	Calibration: Zero Volts
2	Pressure, IR Tape Recorder	Temperature, IR Tape Recorder
3	Calibration: -1.0 Volt	Calibration: -1.0 Volt
4	Temperature, IR Tape Recorder	Pressure, IR Tape Recorder
5	Calibration: -2.0 Volts	Calibration: -2.0 Volts
6	Calibration: -2.5 Volts	Calibration: -2.5 Volts
7	"X" String Battery Output: -28 Volts	"X" String Battery Output: -28 Volts
8	"Y" String Battery Output: -28 Volts	"Y" String Battery Output: -28 Volts
9	"Z" String Battery Output: -28 Volts	"Z" String Battery Output: -28 Volts
10	Main Load Bus. -28 Volts	Main Load Bus: -28 Volts
11	Regulated -24.5 Volts, System No. 1	Regulated -24.5 Volts, System No. 1
12	Regulated -24.5 Volts, System No. 2	Regulated -24.5 Volts, System No. 2
13	Regulated -13.0 Volts, System No. 1	Regulated -13.0 Volts, System No. 1
14	Regulated -13.0 Volts, System No. 2	Regulated -13.0 Volts, System No. 2
15	Vertical Sync Pulse, Clock No. 2	TV Xmtr Power Converters, Systems 1 and 2
16	Horizontal Sync Pulse, Clock No. 2**	Temperature ‡, Base at 130° location
17	Vertical Sync Pulse, Clock No. 1	TV Xmtr Drive Voltages, Systems 1 and 2
18	Horizontal Sync Pulse, Clock No. 1**	Temperature †, Base, at 130° location
19	Vidicon High Voltage, Systems 1 and 2	Vidicon High Voltages, Systems 1 and 2

TABLE VIII-1. TELEMETERED PARAMETERS: TIROS VII (Continued)

Telemetry Switch Position No.	Parameter (136.23-Mc Beacon Channel B)	Parameter (136.92 Mc Beacon Channel A)
20	Temperature ‡, Base, at 130° location	Temperature*, Base, at 130° location
21	Fil. and Focus Current, Vidicon No. 1	Fil. and Focus Current, Vidicon No. 1
22	Fil. and Focus Current, Vidicon No. 2	Fil. and Focus Current, Vidicon No. 2
23	"Home" Position of Rocket Switch and ETP "ON" indication	Temperature*, Solar Cells, at 3-inch radius
24	Temperature*, Inner Top Skin, at 3-inch radius	Solar Cell Array Output Voltage
25	Temperature*, Inner Top Skin, at 12-inch radius	Temperature ‡, TV Camera No. 2
26	Solar Cell Array Output Voltage	Temperature ‡, TV Xmtr No. 1
27	Temperature †, Base, at 130° location	Temperature ‡, Beacon Xmtr No. 2
28	500-cps Converter for Tape Recorder No. 1	500-cps Converter for Tape Recorder No. 1
29	500-cps Converter for Tape Recorder No. 2	500-cps Converter for Tape Recorder No. 2
30	Temperature*, Side Panel No. 2	Temperature ‡, Clock No. 2
31	Temperature*, Solar Cells, at 3-inch radius	Temperature ‡, Battery Package
32	TV Xmtr Power Converters, Systems 1 and 2	Vertical Sync Pulse, Clock No. 2
33	Temperature*, Base, at 130° location	Horizontal Sync Pulse, Clock No. 2**
34	TV Xmtrs Drive Voltage, Systems 1 and 2	Vertical Sync Pulse, Clock No. 1
35	Temperature ‡, TV Camera No. 2	Horizontal Sync Pulse, Clock No. 1**

TABLE VIII-1. TELEMETERED PARAMETERS: TIROS VII (Continued)

Telemetry Switch Position No.	Parameter (136.23-Mc Beacon Channel B)	Parameter (136.92 Mc Beacon Channel A)
36	Temperature ‡, TV Xmtr No. 1	Temperature*, Inner Top Skin, at 3-inch radius
37	Temperature ‡, Beacon Xmtr No. 2	Temperature*, Inner Top Skin, at 12-inch radius
38	Temperature ‡, Clock No. 2	Temperature*, Side Panel No. 2
39	Temperature ‡, Battery Package	"Home" Position of Rocket Switch and "On" indication
40	"Home" Position	"Home" Position

*Temperature Sensor Range: -30 to +100°C
†Temperature Sensor Range: 0 to +40°C
‡Temperature Sensor Range: -20 to 10°C
**Only the horizontal sync pulses of the system in operation are telmetered

At the ground station, the beacon transmissions are received by two pairs of R390A receivers, each pair connected in polarization diversity combination. The telemetry data is demodulated by means of a Sanborn Model 150-2800 preamplifier and is recorded on a strip chart by a Sanborn Model 152-100B recorder. Both the satellite-borne and the ground-based components of the subsystem are designed to provide a data accuracy of $\pm$ 5 percent of full scale on the Sanborn recorder.

The functioning of the Sanborn recorder at the ground station is checked once each day. An audio oscillator is used to generate frequencies corresponding to those produced by the SCO for input voltages over the range from -2.5 to +2.5 volts in 0.5-volt increments. The results of these daily calibration checks are reported to the TIROS Technical Control Center and to AED. In addition, each channel is calibrated at 1300 and 1200 cps before each satellite pass. The calibration marks thereby obtained are recorded at the beginning of the Sanborn recording for that pass.

Compensation for the slight frequency drift caused by aging of components and variations in temperature and operating voltages is afforded by a calibration system built into the satellite. Four of the 39 data-sampling points in the telemetry readout are calibration points whose voltages are determined prior to launch. At the start of each telemetry transmission, the four known voltages are applied to the input of the SCO. The actual deflections of these four telemetry points are then plotted against the deflections obtained during prelaunch measurements, to provide calibration curves for interpreting the

remaining 35 points. The calibrated voltage values for these four telemetry points are given in Table VIII-2.

TABLE VIII-2. MEASURED TELEMETRY CALIBRATION VOLTAGES (INPUTS TO SUBCARRIER OSCILLATORS)

Telemetry Switch Position	136.23-Mc Beacon	136.92-Mc Beacon
1	0.000	0.000
3	-1.007	-1.007
5	-2.013	-2.013
6	-2.516	-2.516

Immediately after the completion of each telemetry transmission, a second calibration of the ground station equipment is performed to check the response of the telemetry-recording system. After this calibration is completed, a standard overlay chart is placed over the recorder strip chart to locate any extreme or unusual indications.

Each 1-year timer aboard the TIROS VII satellite contains two normally closed micro-switches which are in series with the power-supply lead to each beacon transmitter. Operation of the switches in either timer would disable both beacon transmitters. In each unit, the timing mechanism, a battery-operated, electronically controlled, tuning fork, drives a ratchet-pawl arrangement which, in turn, drives a switch-actuating cam. The timers were set to irrevocably open the beacon power line after approximately 12 months of orbital operation.

B. PERFORMANCE EVALUATION

The TIROS VII telemetry and tracking subsystem operated reliably, transmitting strong tracking signals and providing consistent telemetry data throughout the 30-month period covered by this report. A typical telemetry recording is shown in Figure VIII-1.

The performance of both beacon transmitters throughout this period was very satisfactory. Beacon signal-strength data compiled by the CDA stations for TIROS VII indicated that beacon RF power, was greater than the 50-mw minimum required by specifications. The high consistency and correlation of the telemetry data gave proof of proper operation of the subcarrier oscillators.

Proper operation of the telemetry switches was also indicated by consistent telemetry data; the stepping rates of the switches were normal as shown by the chart recordings.

Figure VIII-1. Typical TIROS VII Telemetry Data Recording

The one-year timers did not operate and it is believed that the separate batteries which power these units degraded during the year in space. No actual determination of the cause of failure can be made.

IX. SATELLITE DYNAMICS CONTROL

A. GENERAL

The four devices used on the TIROS VII satellite to provide dynamics control are essentially the same as were used on the previous TIROS satellites. These devices are:

(1) A "Yo-Yo" de-spin mechanism.

(2) Spin-up rockets.

(3) A TEAM (Turned Energy-Absorbing Mass) precession damping mechanism.

(4) A magnetic attitude-control device.

B. DE-SPIN MECHANISM

1. Function

The de-spin mechanism is designed to effect rapid reduction of the spin rate imparted by the second-stage rocket, nominally 126 rpm, to an operational value, nominally, 8 to 12 rpm. The operational range lies between a minimum required for satellite stability and a maximum above which the satellite's spin begins to affect TV resolution.

A "Yo-Yo" mechanism of essentially the same design as was used successfully on TIROS I through VI was used on TIROS VII to achieve the spin reduction. This mechanism consisted of a pair of weights attached to the ends of light steel cables, the other ends of which were engaged at diametrically opposite points on the satellite's circumference by means of simple hook-and-eye release devices. From these points, the cables were wrapped around the periphery of the satellite just above the baseplate; the weights were attached to the satellite by explosive-release mechanisms. Operation of the release mechanisms was initiated automatically shortly after separation of the satellite from the rocket. A back-up means for actuating the mechanism by ground command was also provided.

When the weights were released from the body of the spinning satellite, they tended to move tangentially away from its surface, restrained only by the tension in the cables. As the weights moved outward, the cables unwrapped until, when extended to their full

lengths, they were released from the satellite by the disengaging of the hook-and-eye devices. The temporary increase in the satellite's moment of inertia while the cables were still attached to the satellite but the weights were at increasingly greater distances from its spin axis, caused the reduction in spin rate. (To conserve angular momentum, the satellite's angular velocity decreased as its moment of inertia increased.) The release of the weights and cables after the de-spin had been accomplished restored the moment of inertia to approximately the initial value.

During the calibration phase of the test program, the spacecraft's moment of inertia was measured and the de-spin weights and cable lengths necessary to achieve the desired final spin rate were calculated. These calculations were based on an initial spin rate of 126 rpm and the weights and cable lengths were chosen to provide a de-spin ratio of 0.079, to yield a final spin between the lower operational limit of 8 rpm and the upper limit of 12 rpm.

2. Performance Evaluation

The actual spin rate of the third-stage rocket and spacecraft combination was 128 rpm, 2 rpm above the nominal value. The de-spin mechanism activated normally, approximately 4.5 minutes after separation of the satellite from the third-stage rocket. After spin down, the satellite spin rate was 8.33 rpm. The de-spin ratio was thus 8.33/128, or 0.065. This value is somewhat lower than the theoretical value of 0.079 which is based on the measured satellite moments of inertia, an initial spin rate of 126 rpm, the measured cable lengths, and the weights of the de-spin masses. The device had, therefore, removed more of the satellite's rotational energy than could be accounted for by the formula used to obtain the theoretical ratio. The percentage of error, relative to the nominal initial spin rate, was 1.67/126 x 100, or 1.35 percent.

C. SPIN-UP ROCKETS

1. Function

The satellite's spin rate is gradually reduced in orbit because eddy currents induced in current-conducting parts of the satellite as the result of its passage through the earth's magnetic field produce fields which oppose the inducing field. In order to maintain a spin rate above 8 rpm, (the minimum spin required for stability) the satellite is equipped with spin-up rockets which can be fired in pairs by ground command. As on the previous TIROS satellites, TIROS VII was equipped with five pairs of spin-up rockets, the two rockets in a pair being located diametrically opposite each other. The rockets were designed to produce an increase in the spin rate of approximately 3.5 rpm as the result of the firing of each pair. The theoretical spin-up value differs for each satellite because of different moments of inertia.

2. Performance Evaluation

The spin-up history of TIROS VII is given in Table IX-1.

TABLE IX-1. TIROS VII SPIN-UP DATA

Date (Orbit)	Spin Rate Before Spin-Up (rpm)	Spin Rate After Spin-Up (rpm)	Increase in Spin Rate (rpm)
July 13, 1963 (355)	7.955	9.658	1.703
October 19, 1963 (1809)	8.32	10.084	1.764
March 9, 1964 (3910)	7.99	11.1	3.11
September 23, 1964 (6834)	8.224	11.023	2.799
March 30, 1965 (9606)	8.074	11.204	3.130

The below-normal spin increase that occurred on orbit 355 was analysed to determine the nutation angle of the satellite's spin axis immediately before and immediately after the spin up. The following formula for the half-angle of nutation was used:

$$\frac{\theta}{2} = \frac{\omega \tan \gamma \ \Delta T_{max},}{2 \sin (\pi \ K\psi}$$ *

where

ω is the average spin rate during the period considered;

γ is the sun angle;

ΔT_{max} is the maximum deviation in time between revolusions nutation angle; and

*The following assumptions are implicit in the formula and hold true for the case cited:

1. $\frac{\theta}{2}$ is smaller than 8 degrees,
2. The change in precession angle is small enough to be negligible during the period under examination.
3. The sun angle (γ) is no greater than 80 degrees.

$K\psi$ is equal to $\left(1 - \frac{i_s}{i_t}\right)$

i_s, the moment of inertia about the spin axis (equal to 160.12 in-lb-sec^2), and

i_t, the moment of inertia about the transverse axis (equal to 120.84 in-lb-sec^2).

Therefore,

$$K = 1 - \frac{i_s}{i_t};$$

$$= - 0.327;$$

where the sign indicates the direction of nutation and is not significant.

Calculations made for the 26 rotations immediately preceeding the spin up on orbit 355 yield the following values:

Total time of period: 195.9 seconds,

Average spin period (T_{avg}): 7.532 seconds,

ΔT_{max}: 0.015 second, and

γ : 54.4 degrees.

Then;

$$\omega = \frac{2}{T_{avg}} \qquad (57.3)$$

$$= 47.8 \text{ degrees per second,}$$

and

$$\sin \pi K\psi = 0.855.$$

Therefore,

$$\frac{\theta}{2} = \frac{(47.8)\ (\tan 54.4)\ (0.015)}{2\ (0.855)}$$

$$\frac{\theta}{2} = 0.585 \text{ degree.}$$

Immediately after the spin up on orbit 355, the following values were obtained for a period of 28 revolutions:

Total time of period: 172.9 seconds,

T_{avg}: 6.1868 seconds,

ΔT_{max}: 0.123 second, and

γ: 54.4 degrees.

The half-angle of nutation after spin-up was therefore:

$$\frac{\theta}{2} = \frac{(58.3)\ (\tan 54.4)\ (0.123)}{2\ (0.855)}$$

$$= 5.86 \text{ degrees.}$$

This was an abnormally large nutation angle as evidenced by the more typical angles obtained for spin-ups on previous TIROS satellites. On TIROS IV, for example, the nutation angles obtained immediately following two spin-ups were 3.39 degrees and 2.74 degrees. Furthermore, the spin-up of TIROS VI on orbit 5286, which also produced a spin increase of about one-half the nominal value, resulted in a nutation angle of 5.66 degrees, very close to the nutation angle of 5.68 degrees of TIROS VII after spin-up on orbit 355.

The large nutation angle indicates that an unbalanced torque was applied to the satellite during rocket firing, and the spin increase of approximately one-half the nominal increase therefore suggests that one of the rockets in the pair did not fire.

Because the rockets used on TIROS VII had been stored for a period of a year and one-half, a rocket test program was conducted at AED to determine if aging or other variable conditions affected rocket performance. The tests are described in Appendix A of this report. It was concluded from the test results that duration of storage, exposure to environmental qualification testing, and other variable conditions did not degrade rocket performance. Thus, while it is believed that the cases of low spin increase were the result of only one rocket in a pair firing, it has not been possible to determine why one rocket failed to fire in each case.

The other firings of spin-up rockets on TIROS VII, on orbits 3910, and 6834, produced spin increases closer to the nominal value. Although the spin increase on orbits 6834 and 9609 was slightly low, it was not low enough to be considered the result of one rocket not firing. On orbit 9606, the spin rate was increased from 8.07 rpm to 11.20 rpm, a normal increase of 3.13 rpm. The precession damping device maintained nutation at a very small value as was apparent in the TV photographs. The fact that these rocket pairs performed normally after 9, 15, and 21 months, respectively, in

the space environment is more evidence that aging was not the cause of the earlier anomalies. It is also evidence that the detection circuit for the spin-up function and the rocket switch were in normal condition and probably did not cause the low spin increases on orbits 355 and 1809.

Figure IX-1 shows the number of days it takes for the spin rate to decrease a rate of 1 rpm. This rate of spin decay was compiled from the spin-rate data obtained from TIROS VII since the firing of the fifth and last unused pair of spin-up rockets on March 30, 1965 (orbit 9606). At a later date, the rocket-firing selector switch was sequenced through all its steps and no additional spin-up occurred.

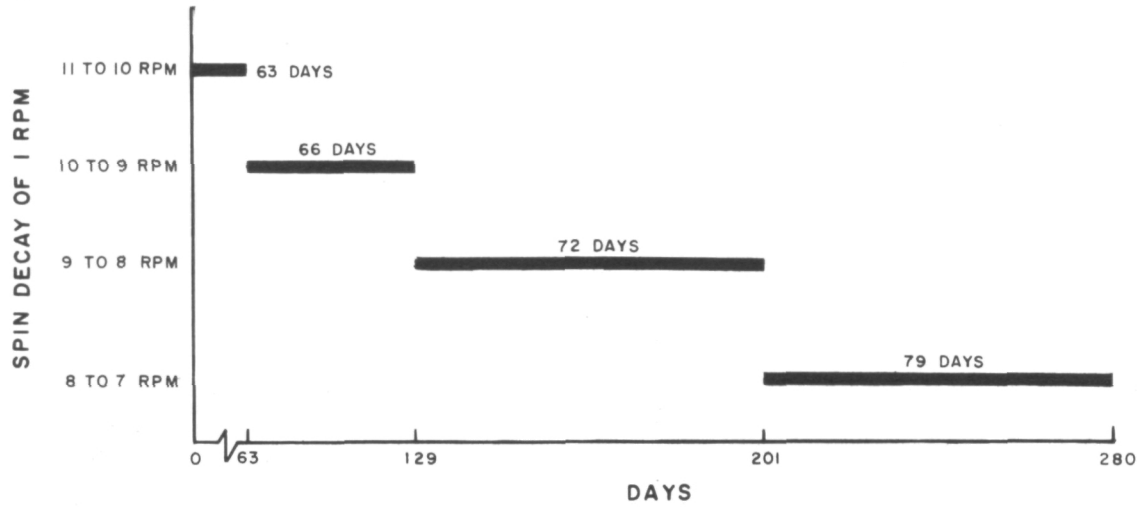


Figure IX-1. Rate of Spin Decay vs Days from Spin-up

At the end of December, 1965, the spin rate had decayed to 7.253 rpm. A displacement of picture principal point from frame-to-frame as a result of spin-axis wobble due to low spin rate was indicated in TIROS Daily Progress Report No. 141 for January 17, 1966. This indication was not substantiated by an evaluation of TIROS VII S-9 data at RCA, since no regular sinusoidal patterns with amplitudes exceeding the acceptable tolerances were observed in the spin-period data.

D. PRECESSION DAMPING DEVICE

1. Function

The precession damping device is designed to reduce the nutation or "wobble" of the satellite's spin axis to a small value soon after separation of the satellite from the third-stage rocket and after any other perturbation of the spin axis such as might be caused by firing of spin-up rockets. The device is tuned energy-absorbing mechanism which converts the energy of nutation into heat. Nutation of the satellite forces the movement of small weights back and forth along slightly curved monorails mounted

with their chords parallel to the spin axis. The friction between the weights and the rails dissipates some of the energy in heat as the weights travel first in one direction and then in the other until the nutation angle is reduced to a very small value.

2. Performance Evaluation

The TEAM mechanism has performed extremely well on TIROS VII. Calculation of the nutation angle before spin-up on orbit 355 showed the half-angle to be 0.586 degree, which gives an indication of the effectiveness of the mechanism in maintaining a low nutation angle. Although other determinations of the nutation angle were not made, it was apparent from the positions of picture centers in the TV picture sequences that the nutation angle was consistently small.

E. ATTITUDE PREDICTION, MEASUREMENT AND CONTROL

1. Function

A coordinated system of attitude prediction, measurement, and control is used to ensure that the TIROS satellite will produce a high percentage of meteorologically useful pictures and that the most effective use will be made of energy available for operation of the satellite's subsystems. The TV cameras are mounted rigidly on the satellite's baseplate; the solar-cells from which the satellite derives the energy required to sustain operation of the subsystems are rigidly affixed to the satellite's side and top surfaces. Thus, satellite attitude determines the picture coverage of each orbit and, by determining the angle and extent of illumination of the solar cells, it determines how much energy is available for use during each orbit. Accurate predictions of attitude make it possible to avoid either overexpenditure of electrical energy or overcharging of the storage batteries and to predict areas where picture taking will be most effective. It is therefore essential that accurate predictions of satellite attitude be available. Further, it is desirable that some means of attitude control be provided, so that an optimum compromise can be achieved to provide good picture geometry, sufficient illumination of desired picture areas, and adequate input to the solar-cell array.

The TIROS predictions are made using a digital computer and a computer program that takes into account the orbital mechanics of the spinning satellite, the effects of differential earth gravity, and the effects of the earth's magnetic field. Other factors which might be expected to exert external forces on an earth satellite are considered to be either negligible at the TIROS altitude (viscous drag of the atmosphere, bombardment by subatomic particles, and radiation pressure) or infrequent and unpredictable (bombardment by meteorites).

The satellite's spin provides a degree of gyroscopic stabilization that tends to keep the spin axis fixed in inertial space. However, two forces, differential gravity and earth magnetism, are of sufficient magnitude to cause attitude changes. The effect of

differential gravity arises from the non-spherical mass distribution of the satellite and is, in general, very small compared with the effect of the earth's magnetism on the satellite. The magnetic effect results from the use of magnetic materials in the satellite's construction and from electrical currents that flow in the wires and assemblies of the satellite. The satellite thus possesses a magnetic dipole which, in its passage around the earth, interacts with the earth's magnetic field, causing a torque to be exerted on the satellite. Because the satellite is a spinning body, this torque results in a precession which continually alters the attitude of the satellite. The strength of satellite's dipole is different in each mode of satellite operation. However, these differences are of little significance, because the satellite's operational modes are in use for only a few minutes of the 100-minute orbit. A significant difference does exist between day-time and night-time dipole monents. This difference results mainly from the difference in direction of current flow in the satellite when the batteries are being charged (day-time) and discharged (night time). Therefore, the important values of dipole moment are the day-time and night-time dipole moments in the standby mode of operation. These values are measured using special equipment during the test and calibration phase of the TIROS program and are constantly re-evaluated while the satellite is in orbit. The need for re-evaluation is the result of state-of-the-art limitations in making the initial measurements and also of an apparent change in the residual dipole as the satellite ages.

In order to null or cancel the satellite's magnetic dipole, or to produce desired attitude changes, a device is used which consists of a rotary stepping switch and a coil of wire wrapped around the baseplate of the satellite. The switch, (magnetic attitude control or MAC switch) is operated by ground command and controls the magnitude and direction of current flow in the coil, thereby producing a different magnetic dipole moment in each switch position. The MAC switch can be used to cause attitude changes of as much as 15 degrees per day and is used to "steer" the spin axis to gain more advantageous sun angles and camera nadir angles as well as to compensate for the satellite's residual dipole.

Chronologically, the attitude program begins with measurements of the dipole moments of the spacecraft (including calibration of the MAC switch) and the computation of initial 90-day pre-launch predictions of satellite attitude. In the course of the dipole moment measurements, permanent trimmer magnets are added to the spacecraft to reduce the residual dipole moments to very small values. These values are recorded and used, together with the planned time of launch, to compute the initial predications. A program of MAC switch operation is also prepared to yield an optimum spin-axis path during the early orbits. However, no changes in settings of the MAC switch are programmed for approximately the first hundred orbits, so that the only dipole moment acting on the satellite during this period is the residual dipole mement. The accuracy of the measured dipole moments can then be evaluated by comparing the predictions with the observed attitude. Trial computations are made until the exact values of the dipole moments that will account for the observed motion are determined. The accuracy of these re-evaluations is apparent from the fact that the predictions based on the new values typically remain valid over several thousands of orbits.

After the satellite has been placed in orbit, its attitude in terms of the celestial coordinates of the normal point of the spin axis, is determined for each orbit. The principle method for attitude determination is the Fujita method, which makes use of the known geometrical relationship of the picture center, the satellite's nadir angle, and the earth's horizon. When a persistent discrepancy appears between the predicted and observed data, the data is carefully evaluated to determine the source of the discrepancy and the best method for restoring agreement. If the discrepancy is constant, a simple shift in data may restore agreement. If the discrepancy is changing, a change in the values of the magnetic dipole moments used in the computer program may bring about agreement.

2. Performance Evaluation

The program of attitude prediction, measurement, and control has been used with increasing effectiveness on all of the TIROS satellites beginning with TIROS II. Improvements in the computer program and in the methods of determining satellite attitude in orbit have contributed to this increased effectiveness. The fundamental validity of the program is apparent from the fact that, even though the satellite operational lives have grown progressively longer, the program has continued to provide highly accurate attitude predictions and effective control.

The predicted and observed coordinates of the normal point of the satellite's spin axis, given in Figures IX-2 and IX-3 show that the attitude prediction and control program for TIROS VII was highly effective during the 18 months of operation in orbit, and continued to be very effective during the evaluation period covered in this report.

An example of the excellent magnetic attitude exercised over the TIROS VII satellite was demonstrated in an experiment performed at the request of NASA. On February 12, 1965, NASA decided to alter the attitude of TIROS VII in order to permit channels 3 and 5 of the 5-channel IR scanning radiometer to view selected areas of the earth through the port in the side of the hat. The purpose of this maneuver was to permit evaluation of possible asymmetrical degradation of the optical system that is used when the IR subsystem views the earth through the port in the baseplate. The torquing maneuver was initiated on February 13 and completed on February 22; the sun angle was decreased from 52 degrees to 1.6 degrees and then increased to 68 degrees. IR data was acquired at the PMR ground station on February 23 during an interrogation on orbit 9093 and on February 24 during interrogations on orbits 9107, 9110, and 9111. This data was dispatched to NASA/CSFC for evaluation. Another torquing maneuver, designed to return TIROS VII to its normal attitude, was initiated on February 23; the maneuver was completed in approximately 8 days. Figure IX-4 illustrates the torquing maneuvers executed during the experiment in terms of gamma angle (from telemetry readout) versus Julian day.

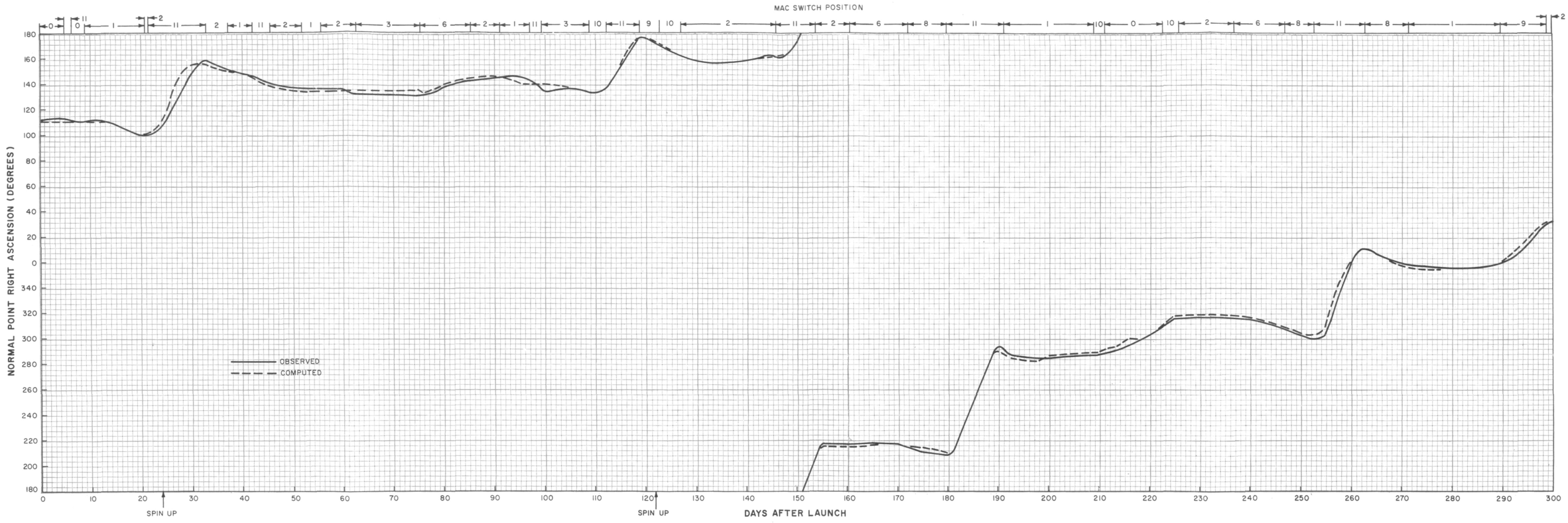


Figure IX-2. Normal Point Right Ascension vs Days After Launch (Sheet 1 of 4)

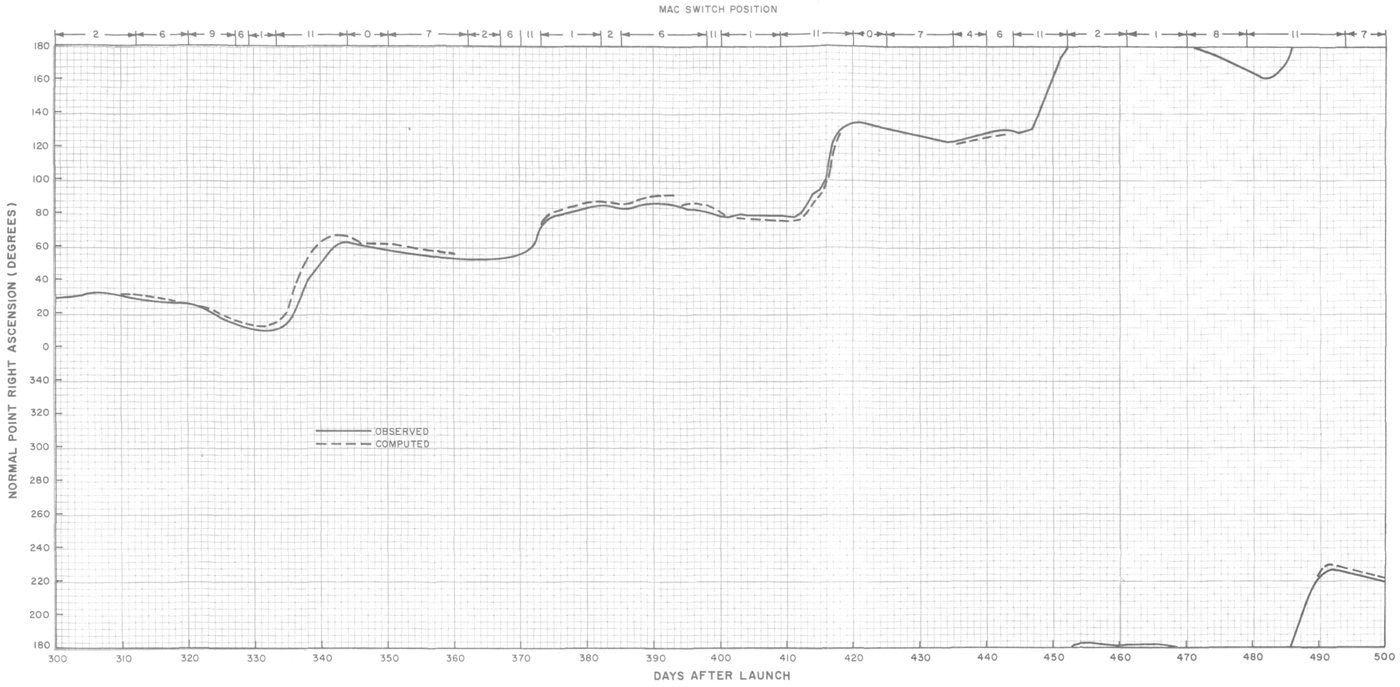


Figure IX-2. Normal Point Right Ascension vs Days After Launch (Sheet 2 of 4)

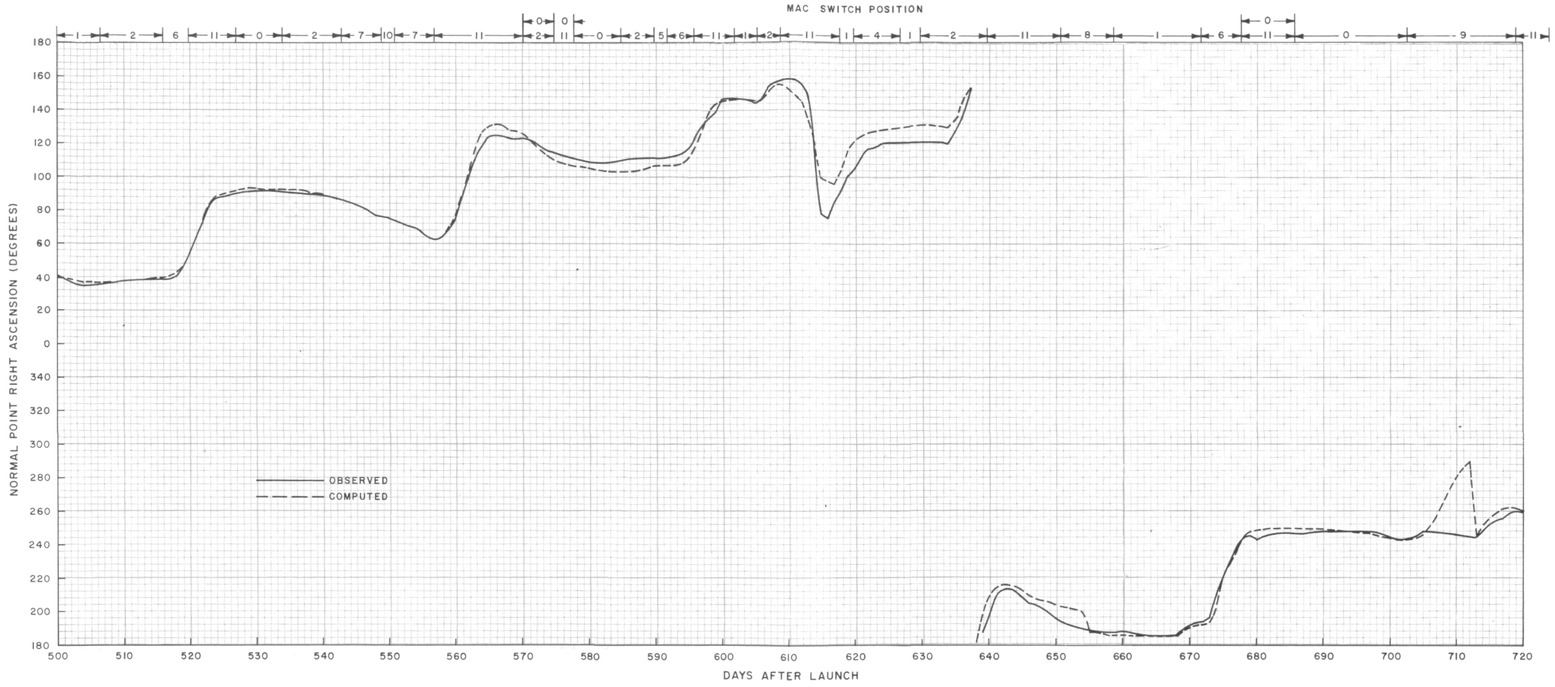


Figure IX-2. Normal Point Right Ascension vs Days After Launch (Sheet 3 of 4)

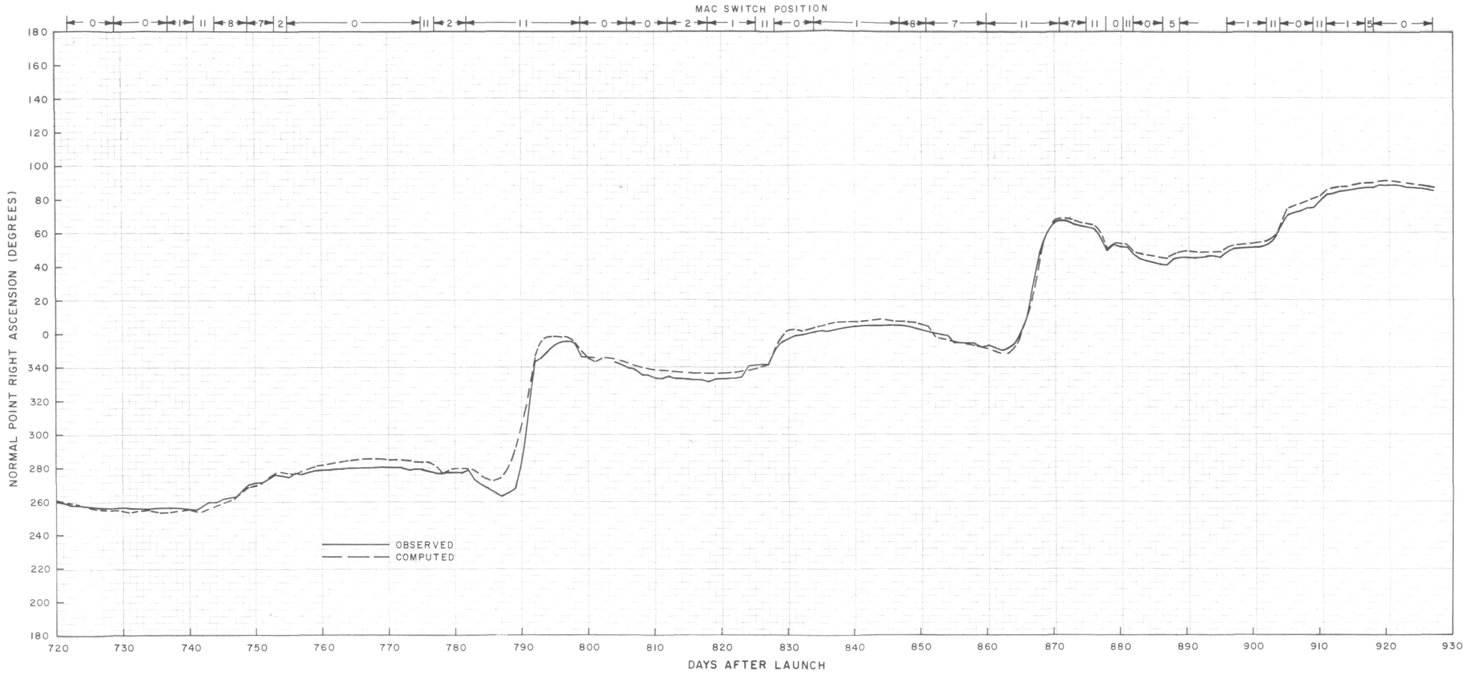


Figure IX-2. Normal Point Right Ascension vs Days After Launch (Sheet 4 of 4)

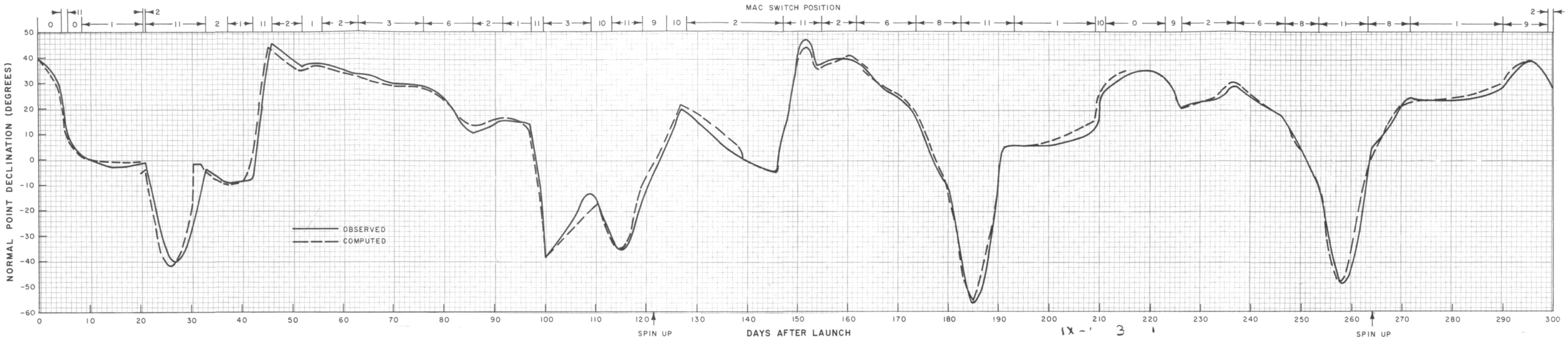


Figure IX-3. Normal Point Declination vs Days After Launch (Sheet 1 of 4)

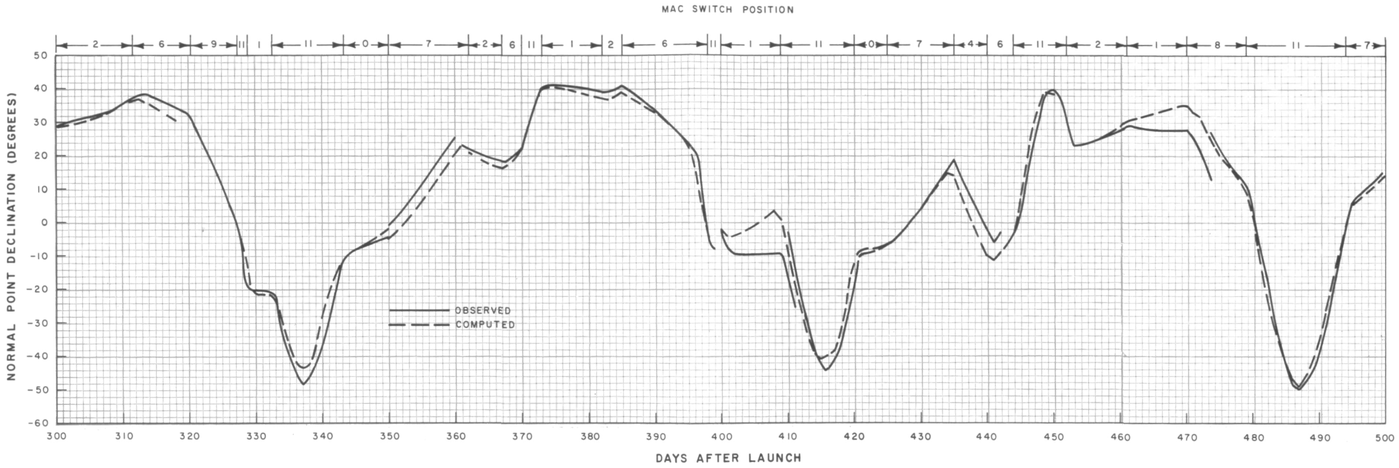


Figure IX-3. Normal Point Declination v's Days After Launch (Sheet 2 of 4)

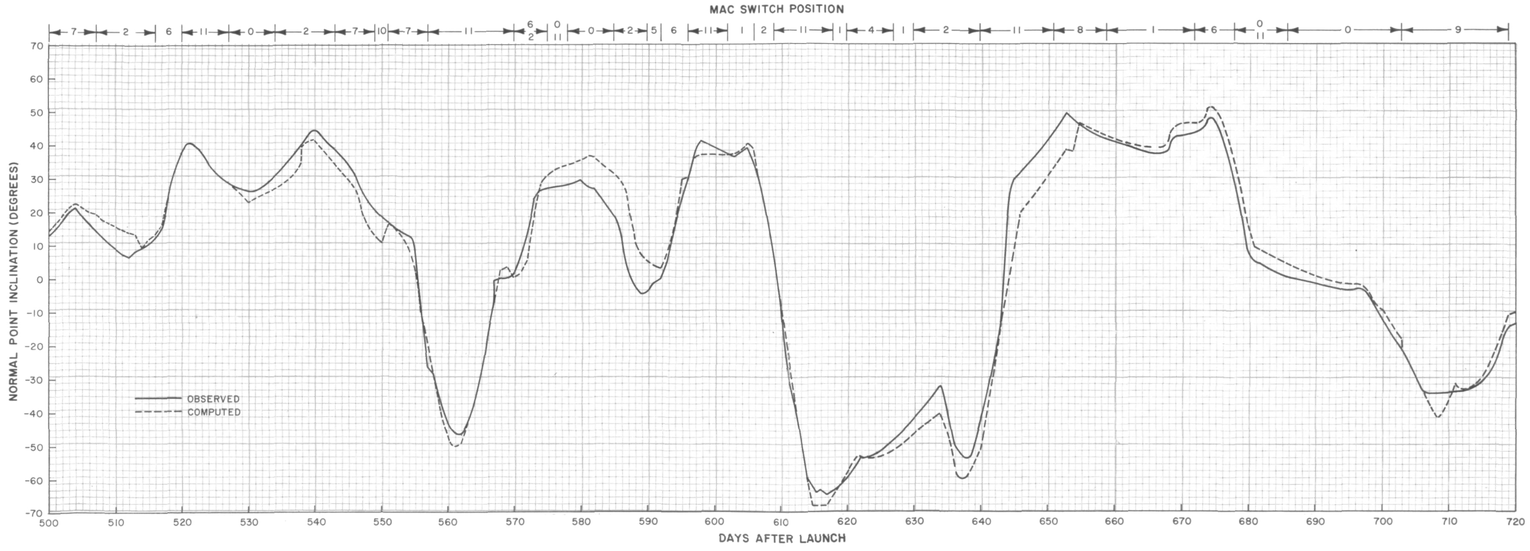


Figure IX-3. Normal Point Declination vs Days After Launch (Sheet 3 of 4)

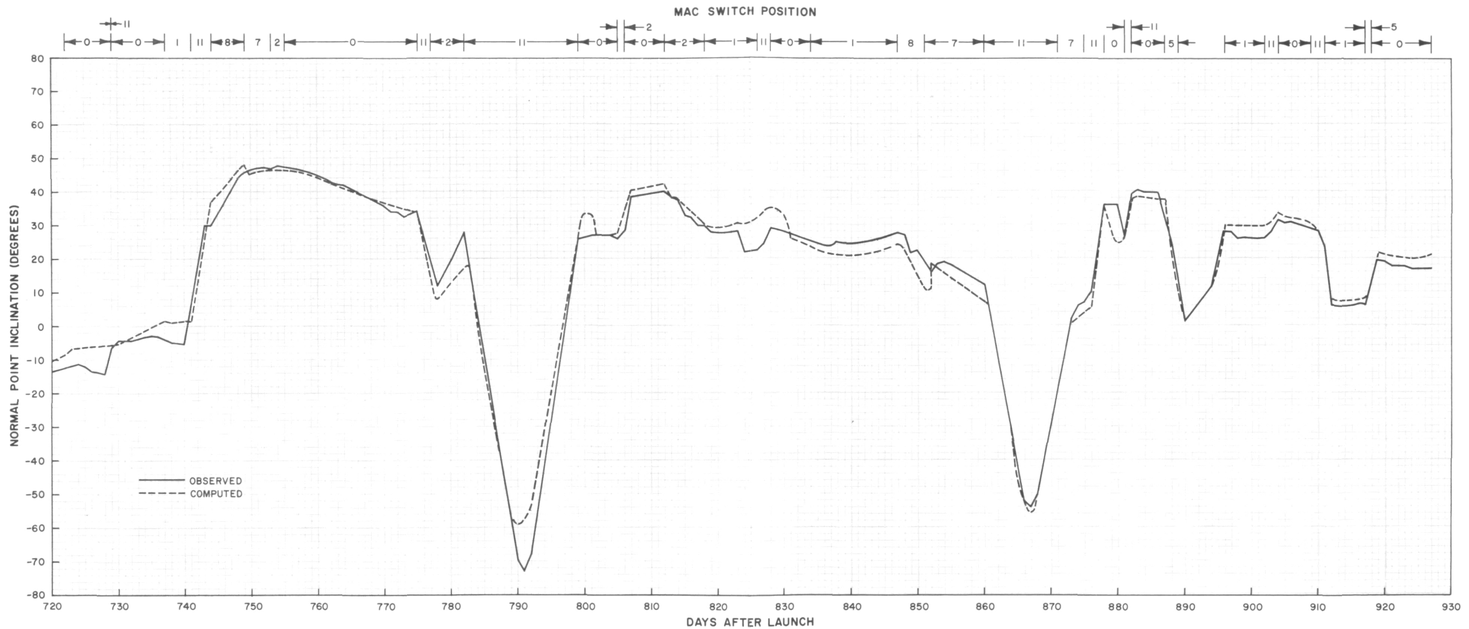


Figure IX-3. Normal Point Declination vs Days After Launch (Sheet 4 of 4)

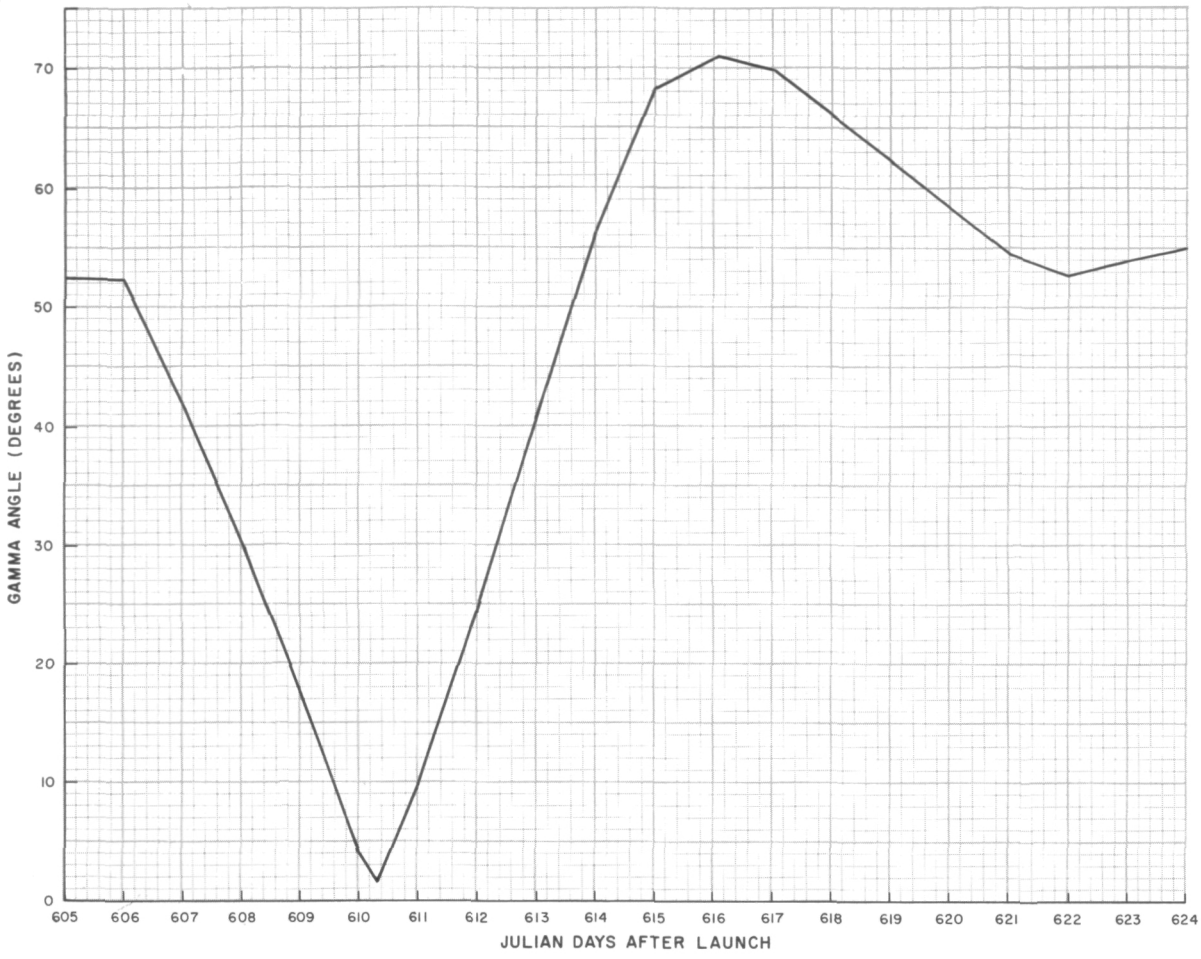


Figure IX-4. Effect of Torquing Maneuver on Gamma Angle

X. ANTENNAS

A. FUNCTION

1. General

The satellite antennas provide the means for the reception of command signals from the CDA ground stations and for the simultaneous radiation of energy from four separate transmitters (two beacon, one IR and either one of two TV). A network is provided for coupling and matching the receivers and transmitters to the antennas and for isolating the four active transmitters and the two command receivers.

The CDA ground station antennas provide for the reception of the TV, IR, and beacon signals from the satellite and for the transmission of command signals to the satellite.

The antennas and the satellite matching and coupling network are the same as those used on the previous TIROS satellites.

2. Satellite Antennas

The command receivers of the satellite utilize a simple dipole receiving antenna consisting of a single vertical "whip." The beacon, TV, and IR transmitters share two crossed-dipole antennas (two frequencies) by means of a coupling and matching network which couples the four antenna segments in phase quadrature to achieve a circularly polarized output. An RF relay switching network is employed to connect the output from one of the TV transmitters to the matching and coupling network. Both beacon transmitters and the IR transmitter are permanently connected to the network.

The matching and coupling network for the transmitting antennas provides:

(1) Coupling of at least two transmitters in each frequency band to the radiating elements with a minimum of feedback between transmitters.

(2) Sufficient isolation to prevent interaction between transmitters operating in different frequency bands.

(3) Division of energy from each transmitter into four branches so that the currents are of equal magnitude in all branches and are properly phased to produce circular polarization.

3. Ground Station Antennas

Signals from the TIROS VII satellite are received by a 60-foot parabolic antenna at the PMR ground station. The Wallops Island ground station is equipped with two antennas. A General Bronze swept-volume efficiency antenna, having a gain of 29 db and similar in design to the antenna at the AED station, is used to receive the 235-Mc signals; a crossed-helix antenna is used for receiving the 136-Mc beacon signals. The 148-Mc command antenna at Wallops Island is mounted on the same gimbling mount as the 136-Mc antenna. At the PMR station, the command antenna is mounted on the upper rim of the 60-foot antenna. The Alaska CDA station makes use of a Blaw Knox 85-foot parabolic dish antenna on an X-Y mount. Dipole elements for 136-Mc and 235-Mc are located at the focal point of the dish. The antennas at all four stations are capable of manual or automatic tracking of the satellite.

B. PERFORMANCE EVALUATION

Performance of the satellite antennas in all frequency ranges was normal throughout the operational life of the satellite. Satisfactory signal strengths from the satellite transmitters have been reported by the CDA stations and by the AED back-up station, indicating that performance of the transmitting antennas and the antenna matching and coupling network has been normal. The consistently good response of the satellite to ground commands gives evidence of satisfactory performance of the command receiving antenna. An evaluation of the satellite command antenna radiation pattern was performed in connection with a general evaluation of satellite response to the clock set commands. This evaluation is presented in Section VI. No anomalies were found to exist in the antenna pattern.

The consistently high signal levels received by the ground stations and the absence of unexplicable signal fading indicate that the satellite transmitting antennas performed normally.

Performance of the ground station antennas is covered in detail in the individual descriptions of ground station operation in Section XIV of this report.

XI. ELECTRICAL POWER SUPPLY SUBSYSTEM

A. FUNCTION

The electrical power for all of the requirements of the TIROS VII satellite is supplied by a solar-energy converter and a group of 63 nickel-cadmium storage batteries. The solar-energy converter consists of an array of 9120 p-on-n, silicon-solar cells, mounted on the top and sides of the satellite structure. During orbital day, when the solar cells are illuminated, the output of the array is used as the satellite's primary power source; any excess power (power not needed by the satellite electronics) is used to charge the storage batteries. In cases where the peak-power requirements exceed the power output of the solar cells, the batteries automatically supply the difference. During orbital night, the storage batteries, which have a total capacity of approximately 11.7 ampere-hours, supply all of the power required by the satellite. Precautions were taken in the design of the subsystem to peevent internal circulating currents through the power-source interconnections and to preclude the total loss of power in the event that a short circuit occurs in one of the cells or batteries.

The storage batteries are electrically connected in three independent groups, each of which is connected to the solar-cell supply through its own current regulator to prevent an excessive rate of charge. The excess power is diverted through a bypass regulator to the main battery-output bus. During orbital night, when the solar cells are passive, silicon diodes in each series row of solar cells prevent the storage batteries from discharging into the solar cells. A similar function is performed by diodes included in each series row of solar cells located on the lateral surfaces of the satellite. Because of the satellite's rotation, each series row of solar cells on a lateral surface is alternately illuminated and then darkened. The diodes prevent the darkened solar-cell rows from loading the illuminated rows.

The storage batteries provide a relatively constant voltage across the solar cells, thereby isolating them from variations in the electrical load. The storage batteries are charged by the solar cells during orbital day and supply all equipment loads during orbital night.

The TIROS VII electrical power supply subsystem is identical to the TIROS VI power supply subsystem. One-half of the 9120 silicon solar cells are of the "gridded" type, having an efficiency of 9.25 percent as compared with the 7.25-percent efficiency of the ungridded cells.

B. PERFORMANCE EVALUATION

1. General

The power supply subsystem on TIROS VII performed extremely well during the period examined. The capability of the subsystem for supplying the electrical energy requirements of the satellite is dependent on proper utilization of the available power by satellite programming as well as on proper performance of the solar array, storage batteries, and regulating and protective circuits. Two factors are prominent in satisfactory power supply performance: (1) maintaining a balance between available energy and energy expended and (2) maintaining a minimum battery voltage of -26 volts.

2. Energy Balance on TIROS VII

Energy available is dependent on the angle of incidence of the sun's rays on the satellite (solar conversion of the cells varies with the angle of incidence of the sun's rays and with cell temperature) and on the percentage of each orbit during which the satellite is illuminated by the sun. The energy available is predicted for each day in orbit from predictions of satellite attitude and orbit path. Energy used is budgeted on a daily basis so that the programming planned for one day will not expend more energy than is converted during that same day by the solar array. The energy available for each orbit day during the evaluation of the first 18 months of operation and the last month covered in this report, December, 1965 is shown in Figure XI-1. Also shown is the daily energy expenditure. On all but three days of the 540-day period evaluated, the energy available exceeded the energy used. On those three days (orbit days 3, 4, and 50), the energy used slightly exceeded the power available for a brief period; the energy balance was quickly restored by proper program planning. In general, the curves indicate good practices in the utilization of available energy on TIROS VII as well as normal performance of the solar array, batteries and power supply circuits.

3. Battery (Unregulated Bus) Voltage on TIROS VII

The daily maximum and minimum unregulated power supply bus voltages telemetered during the evaluation of the first 18 months of operation and December, 1965 are shown in Figure XI-2. This voltage is from 0.5 to 1.0 volt lower than the individual battery-row voltages because of small voltage drops in the germanium diodes that are used to isolate the battery rows from each other.

The nominal unregulated bus voltage at which the power supply regulators cease to provide regulation is 26 volts. If the telemetered, unregulated bus voltage decreases below, and remains below, 26 volts on two successive telemetry readouts, standard procedures call for the immediate suspension of programming until the telemetered

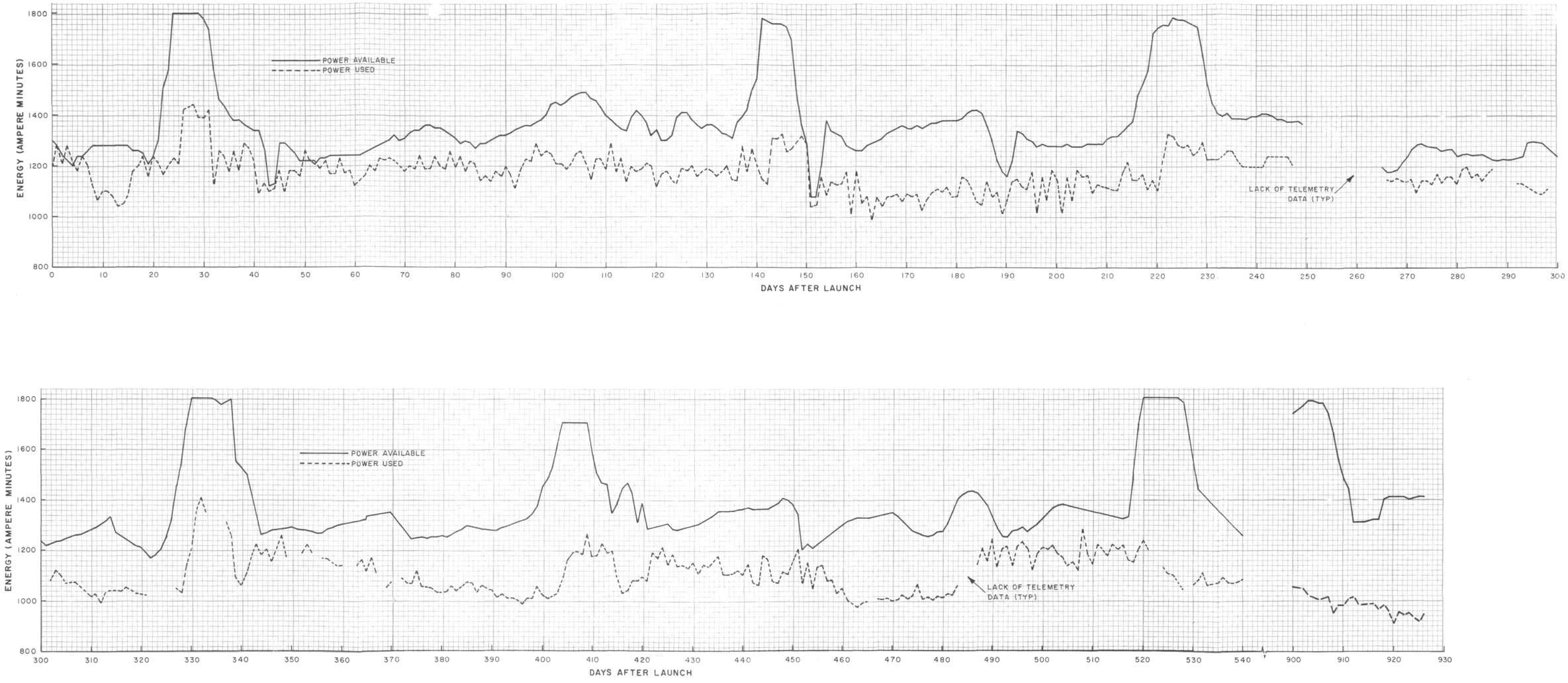
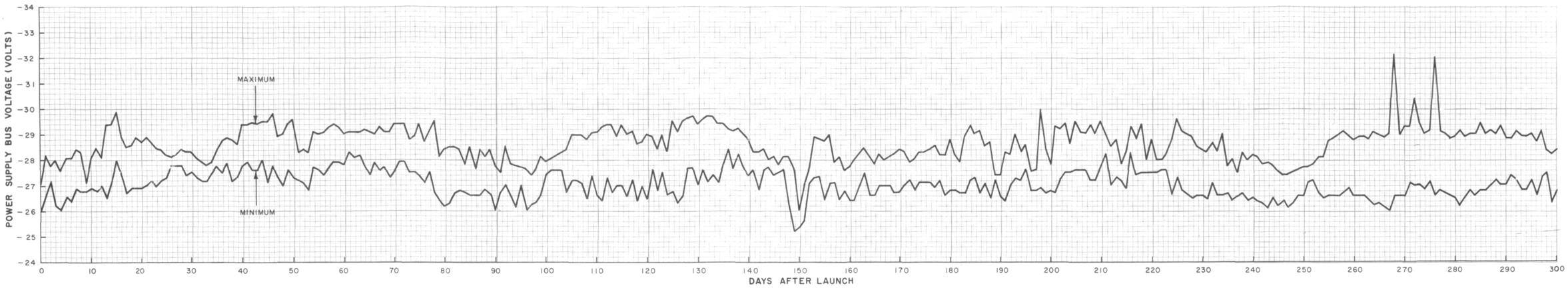


Figure XI-1. Calculated Energy Available and Actual Energy Used vs Days After Launch



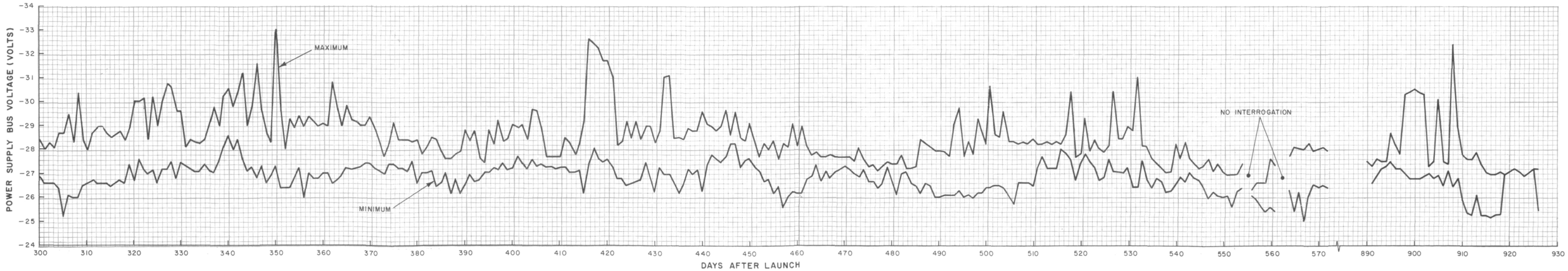


Figure XI-2. Satellite Power Supply (Battery) Voltage vs Days After Launch

unregulated bus voltage returns to normal. On TIROS VII, the telemetered bus voltage remained below 26 volts on only four of 550 days, as follows:

Day	Voltage
81	25.5
118	25.8
150	25.2
224	25.7

Of these, the telemetered readings for days 81 and 224 were found to represent actual voltages of 26 and 26.2 volts, after appropriate temperature compensation was made (using pre-launch temperature calibrations of the telemetry sensors) and were, therefore, above the minimum required for regulation. The low readings during day 118 were found to have occurred on a single night-time orbit (orbit 1742) when three telemetry readouts were taken on the same orbit, thus placing more load on the supply than was indicated in the daily program. It is to be noted that telemetry for the regulated bus voltage during the same three telemetry readouts showed no evidence of any change in regulation. During day 150, the power consumed was approximately equal to the power available. On the seventh orbit of the day (orbit 2224), the third telemetry readout for the orbit yielded the low reading of 25.3 volts. Telemetry during the same orbit showed that the two regulated -24.5 bus voltages aboard the spacecraft differed appreciably, indicating that one of the regulators had ceased regulating. This condition was the result of the marginal status of the spacecraft energy balance, as the result of energy consumption equalling energy available. On the following day, the unregulated bus voltage quickly returned to a normal range of values.

As indicated in Figure XI-2, the unregulated bus voltage decreased below 26 volts during some days in December, 1965. The reasons for this voltage drop are as follows:

(1) Serious degradation of the solar-cell and batteries had taken place.

(2) As shown in Figure XII-7, the satellite gamma angle and percent sun time was less during this period. Therefore, there was less solar energy available as the primary power source for the satellite, and the batteries were required to supply the power difference.

During the latter part of the month, the satellite gamma angle and the power available increased, and, by the careful programming, the total power consummed was reduced. Because of these factors, the unregulated bus voltage returned above its nominal value.

4. Solar Patch Telemetry

A group of 60-series-connected solar cells, located on top of the TIROS VII "hat", is isolated from the remainder of the cells in the solar array and is provided with a

fixed load resistance. The load resistance consists of two 1-percent resistors connected in series to form a voltage divider that provides a telemetry voltage, nominally 2.50 volts under optimum conditions for solar conversion. This solar-cell patch was calibrated during the test and calibration phase of the TIROS VII engineering program so that, during orbital operation of the satellite, the output could be predicted for each orbit as a function of sun angle (α), solar cell temperature and percent sun-time; the telemetered value (V_T) is compared with the predicted value (V_C) to obtain an indication of any changes in solar-cell performance. Any changes due to charged particles or micrometeorite bombardment of the cells can be expected to affect the entire solar array, including the telemetered patch, and are apparent as a deviation of the telemetered from the predicted solar-patch voltage.

A ratio of the values, V_T/V_C, is used to provide a convenient indication of change in condition of the solar cells. A plot of this ratio for the 550-day period of evaluation is shown in Figure XI-3.

Because the calibration curves from which the predicted value, V_C, is calculated are based on absolute measurements, the telemetered value, V_T, should equal V_C at the start of the satellite's life in orbit. However, this was not the case on TIROS VII. The ratio on the first day in orbit was 0.941. The fact that the ratio was not 1 on orbit day 1 does not appear to have been the result of any performance degradation of the solar cells, since the performance of the solar array in supplying the energy required by the satellite was excellent over the entire period examined. Any solar-cell degradation would soon have been apparent from a deficiency in power available (Figure XI-2). Other possible causes, such as contamination of the cells in the patch by rocket exhaust gasses, a partial short circuit in the patch, or a selective bombardment by micrometeorities or charged particles, although unlikely, may have occurred. The actual cause cannot be definitely established.

The ratio V_T/V_C slowly decreased with time, although, as stated previously, the decrease was not accompanied by any appreciable degradation in the performance of the solar array in supplying energy to the satellite. Beginning on day 310, telemetry was not available for plotting V_T. After day 330, the V_T data became erratic and is considered unreliable, and therefore, the ratio V_T/V_C could not be evaluated from day 330.

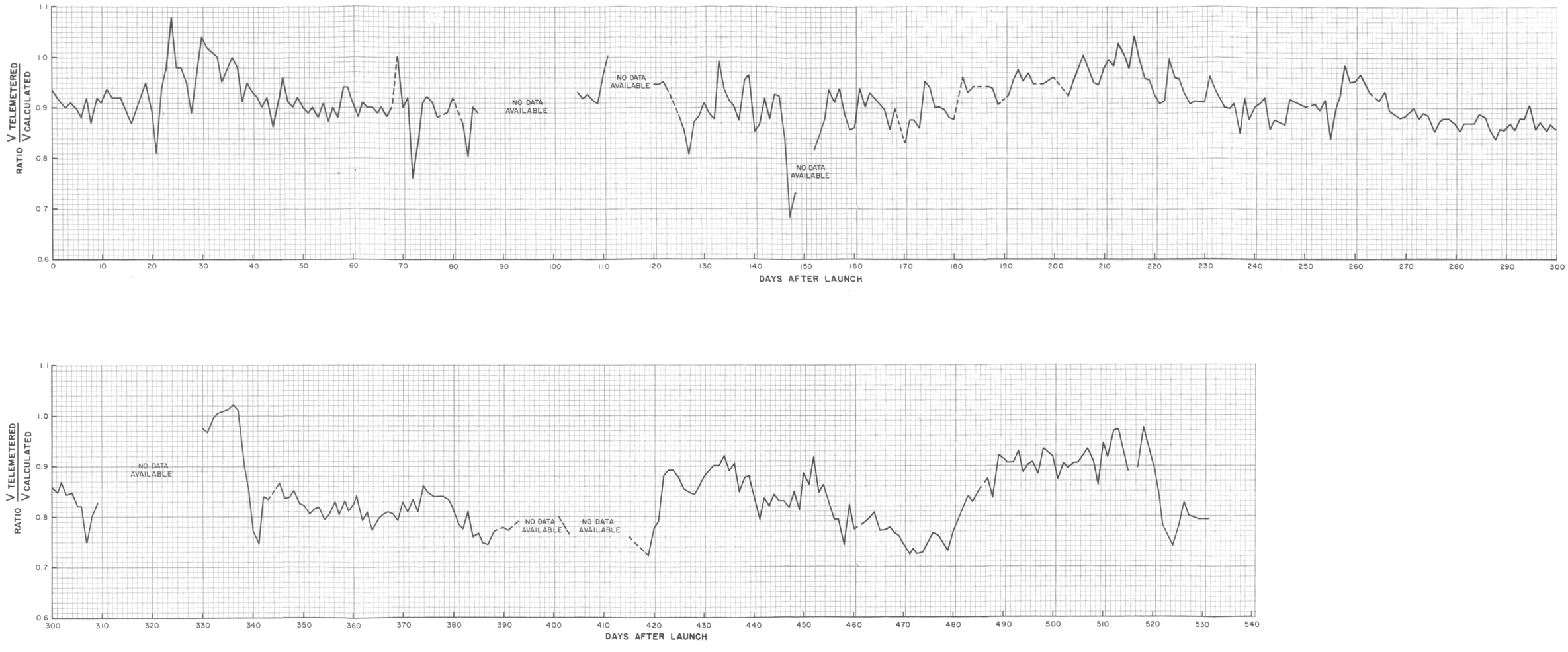


Figure XI-3. Ratio of Telemetered Solar-Cell Patch Voltage to Calculated Patch Voltage vs Days After Launch

XII. SATELLITE THERMAL RESPONSE

A. FUNCTION

The thermal design of TIROS VII is essentially the same as that of TIROS VI, employing the same passive temperature-control techniques to maintain the temperatures of the satellite components within the allowable design temperature extremes and to maintain the temperature of the solar cells within the limits required for good conversion efficiency. Because TIROS VII carries an IR subsystem, the heat contribution of the electronics subsystems is nearly the same as on the TIROS II, III, and IV satellites. Satellite structure and component temperatures are telemetered from 12 points on the satellite and daily maximum and minimum temperatures are plotted. Locations of temperature telemetry points on the satellite and the response characteristics of the telemetry sensors are listed in Table XII-1.

B. PERFORMANCE EVALUATION

On TIROS VII, as on all of the previous TIROS satellites, component temperatures have remained within the design limits, and top and side temperatures have remained within the values predicted for maximum and minimum sun time.

Plots of daily maximum and minimum structure temperatures (top, side, and baseplate), battery temperature, and IR tape recorder temperature, taken from daily telemetry recordings during the first 18 months, and the last month of this report, December, 1965, are shown in Figures XII-1 through XII-5.

A plot of average component temperature for this period is shown in Figure XI-6. Plots of satellite sun (gamma) angle and percent sun time are shown in Figure XII-7. The component temperatures followed closely the values to be expected for variations in gamma angle and sun time and no abnormal thermal patterns were observed.

TABLE XII-1. LOCATIONS AND CHARACTERISTICS OF TIROS VII TEMPERATURE SENSORS

Sensor Number	Location	Temperature Range (Degrees Centigrade)	Scale Factor (Degrees Per Volt)	Conductance-Temperature Response
1	17 inches from baseplate center, on 130-degree radial line	-30 to +100	52	Linear within ±1 percent between -10 and -50 degrees Centigrade
2	17 inches from baseplate center, on 130-degree radial line	-20 to +100	12	Linear within ±3 percent between -20 and -5 degrees Centigrade
3	17 inches from baseplate center, on 130-degree radial line	0 to +40	12	Linear within ±3 percent over entire range
4	Inside satellite top plate on 300-degree radial line at 3-in. radius	-30 to +100	52	Linear within ±1 percent between -10 and +50 degrees Centigrade
5	Outside satellite top plate on 300-degree radial line at 3-in. radius (under solar cells)	-30 to +100	52	Linear within ±1 percent between -10 and +50 degrees Centigrade
6	Inside satellite top plate 15 inches from center on 150-degree radial line	-30 to +100	52	Linear within ±1 percent between -10 and +50 degrees Centigrade
7	Inside satellite side panel No. 2	-30 to +100	52	Linear within ±1 percent between -10 and +50 degrees Centigrade
8	Battery Package	0 to +40	12	Linear within ±3 percent over entire range
9	Outer surface of TV transmitter No. 1	0 to +40	12	Linear within ±3 percent over entire range
10	Outer surface of beacon transmitter No. 2	0 to +40	12	Linear within ±3 percent over entire range
11	Outer surface of TV camera No. 2	0 to +40	12	Linear within ±3 percent over entire range

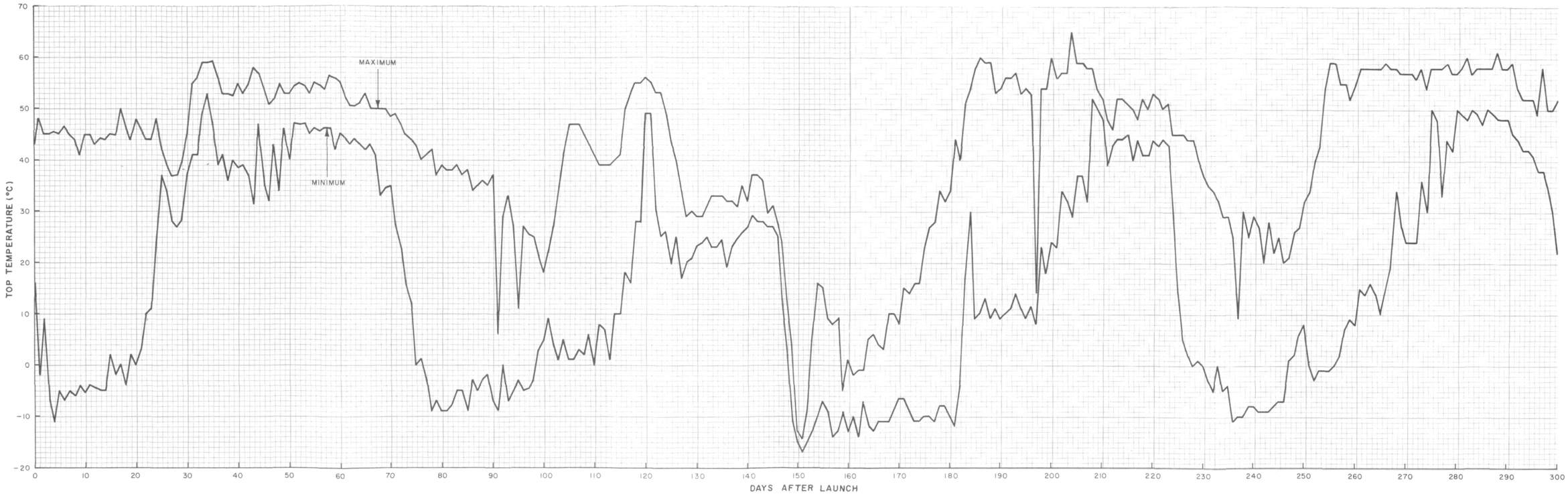


Figure XII-1. Satellite Top Temperature vs Days After Launch (Sheet 1 of 2)

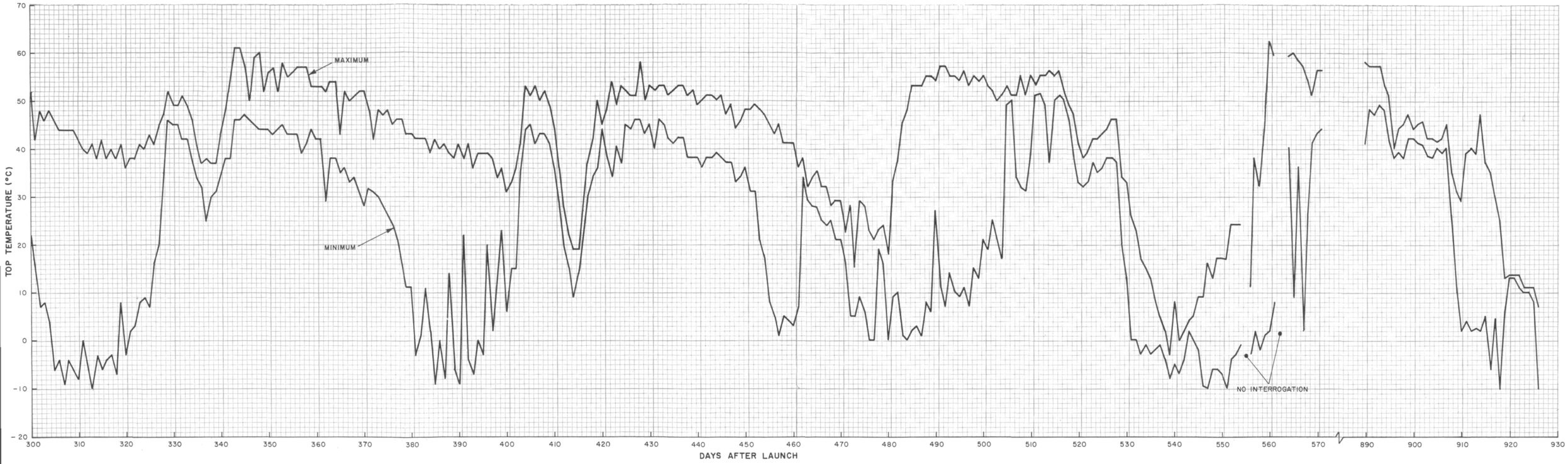


Figure XII-1. Satellite Top Temperature vs Days After Launch (Sheet 2 of 2)

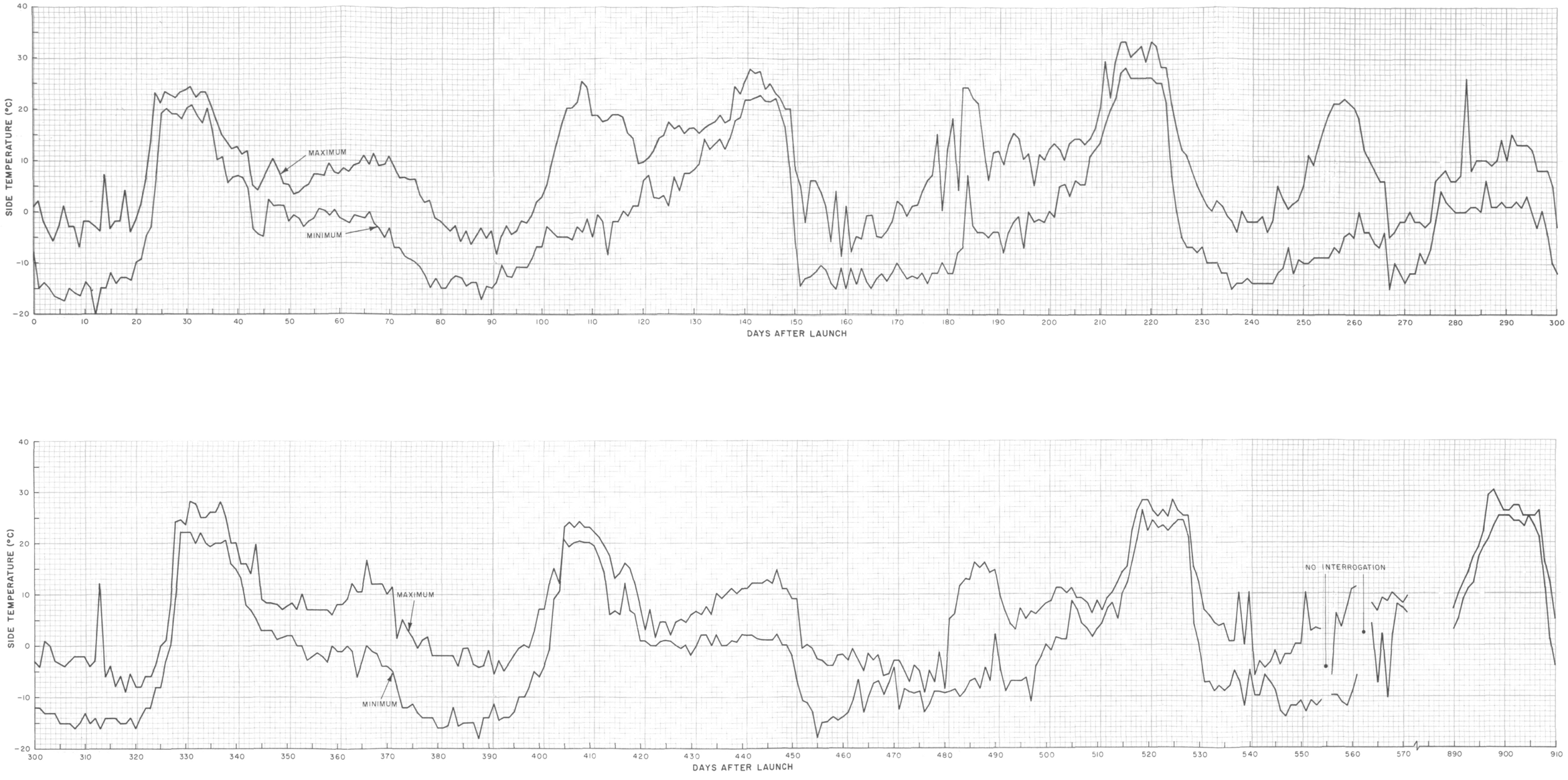
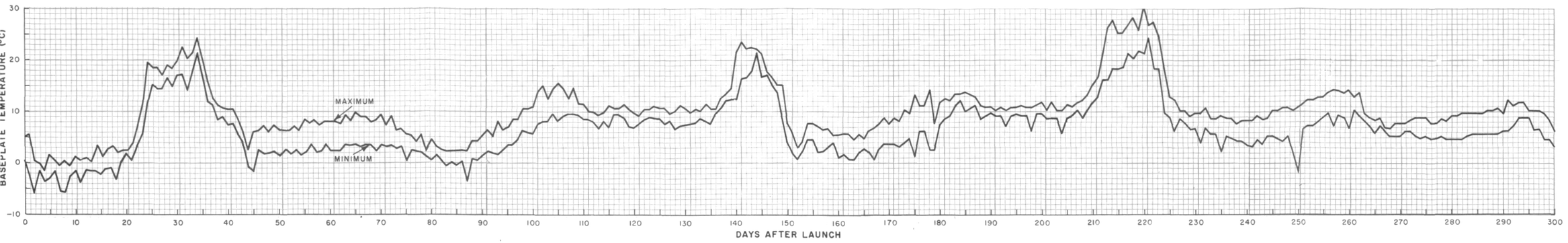


Figure XII-2. Satellite Side Temperature vs Days After Launch



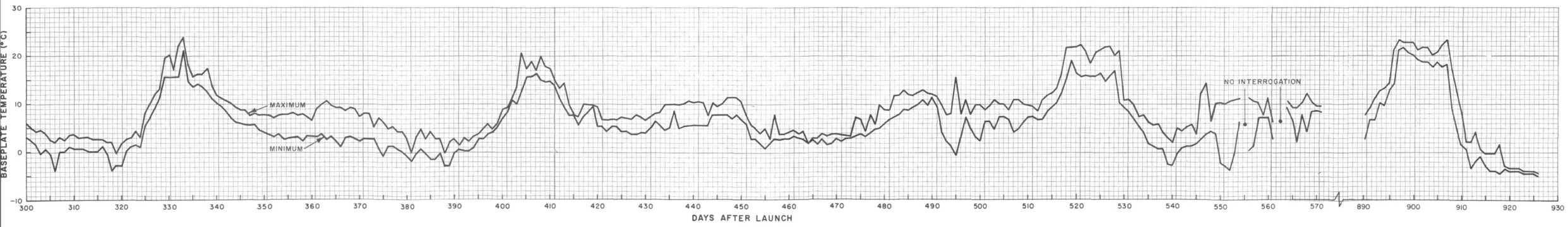


Figure XII-3. Satellite Baseplate Temperature vs Days After Launch

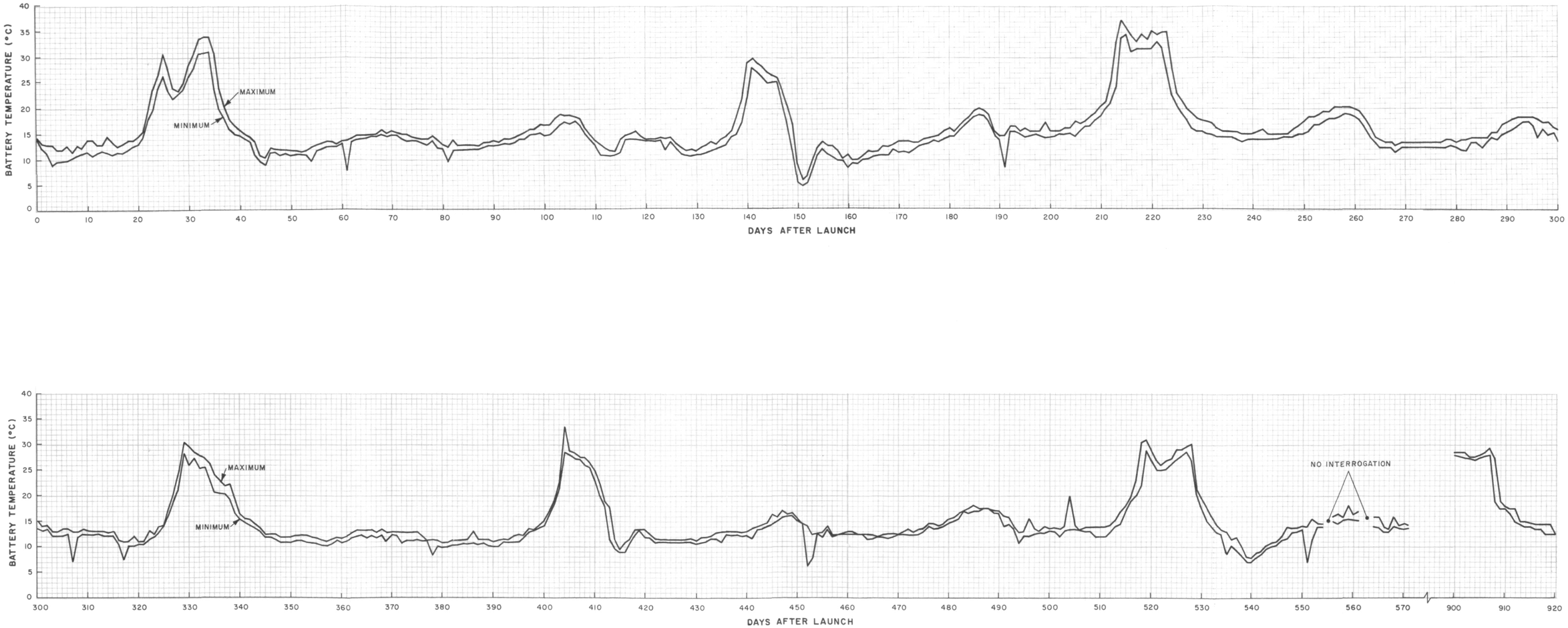
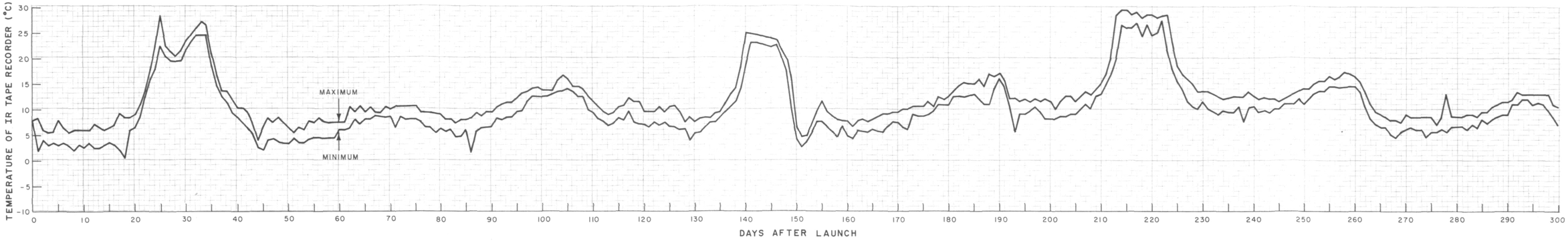


Figure XII-4. Satellite Battery Temperature vs Days After Launch



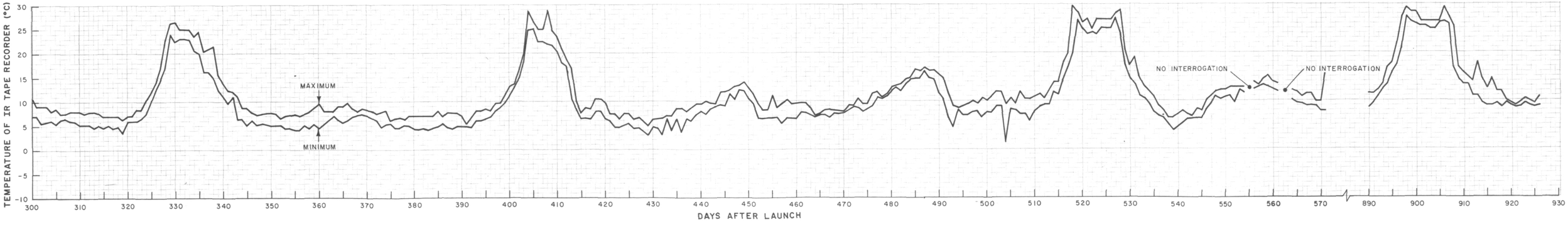


Figure XII-5. Temperature of Satellite IR Tape Recorder

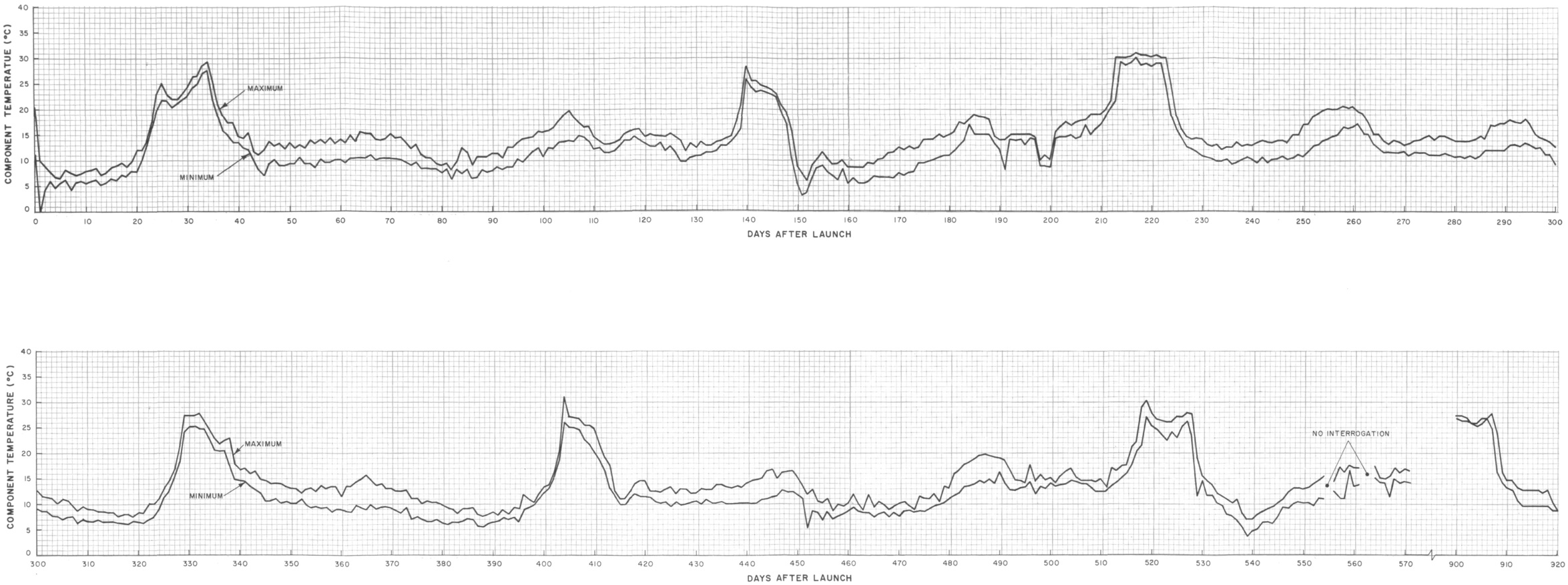


Figure XII-6. Satellite Component Temperature vs Days After Launch

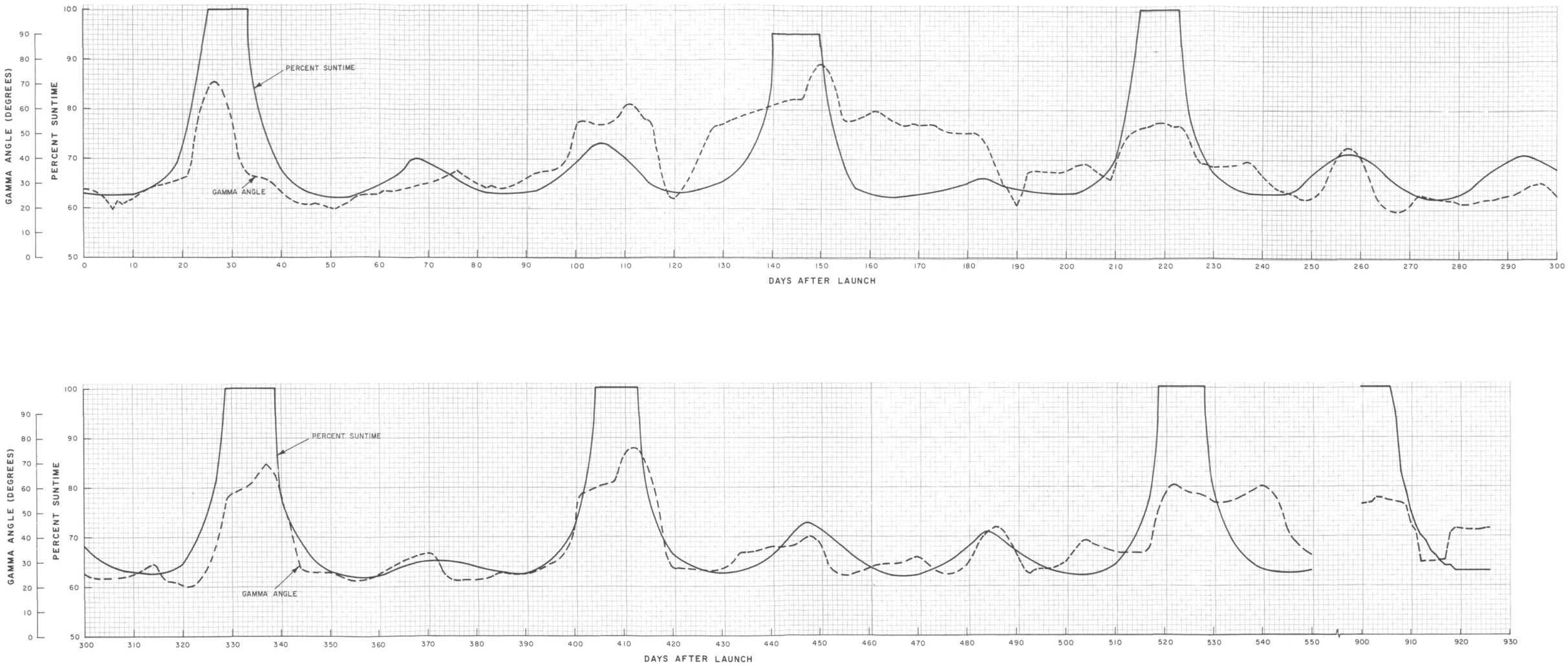


Figure XII-7. Gamma Angle and Percent Suntime vs Days After Launch

XIII. REFERENCE-INDICATOR SUBSYSTEMS

A. INTRODUCTION

The reference indicator subsystems comprise the north-indicator subsystem and the attitude-indicator subsystem. These two subsystems are considered collectively because both supply data required for identifying cloud-picture orientation. The north-indicator subsystem, consisting of nine solar-cell sensors and associated electronics, supplies data from which the north direction in each picture can be determined. The attitude indicator subsystem, consisting of an IR sensor (horizon scanner) and associated electronics, provides data from which the attitude of the satellite's spin axis can be determined.

B. ATTITUDE-INDICATOR SUBSYSTEM

1. Function

The attitude-indicator subsystem used on TIROS VII is essentially the same as the one used on TIROS VI. This subsystem provides data to the ground stations from which the attitude of the satellite's spin axis can be computed. The data is derived from the output of an infrared-sensor unit which scans the earth and space in alternation as the satellite rotates. Heat radiation from the earth causes an electrical output pulse from the sensor during the period in which it scans the earth. This pulse is differentiated and amplified, and then applied as a modulating signal to the telemetry subcarrier oscillators for transmission by the beacon transmitters to the CDA ground stations. Transmission of the attitude information is continuous except when interrupted for 40 seconds at the beginning of each ground station interruption for the sending of telemetry data.

The attitude-indicator subsystem consists basically of a narrow-field, infrared-sensing bolometer and an amplifying and differentiating circuit. The sensor has a 1.5-degree by 1.5-degree square field of view, and it is mounted with its optical axis at an angle of 70 degrees to the top of the spin axis of the satellite. The sensor has a time constant of 2.0 milliseconds, and a spectral response between 7 and 30 microns, which falls off sharply at wave-lengths shorter than 7 microns. The spectral response and time constant were chosen so that uniform and accurate response occurred whenever the field-of-view includes the earth; the sensor is oriented in such a manner that during the operating period it never views the sun directly if attitude variations are of the type predicted. Although no damage would result if the sensor were directly exposed to the sun, such an exposure would produce a spurious output. Varying illumination

and reflectivity on the surface of the earth also generates spurious signals, because the reflected radiation is principally in the wave-bands to which the sensor responds; however, these signals are cancelled at the ground stations by a time-discrimination process utilizing specially designed inhibit circuits.

The electrical output of the sensor is a trapezoidal wave. In order to avoid stability problems with either low-frequency or d-c amplifiers, and in order to eliminate drift caused by changing ambient temperature, the wave is differentiated and amplified by the intermediate electronics before being transmitted from the satellite.

At the ground station, the attitude data is routed to the attitude-pulse selector. The attitude-pulse selector separates the valid leading and trailing edges of the earth-scan pulse from spurious amplitude changes caused when cloud transitions are scanned. Subsequently, the leading edge of a valid pulse is developed into a pulse representing a sky-earth transition and the trailing edge of a valid pulse is developed into a pulse representing an earth-sky transition. These two pulses are then applied to a digital time-measuring device to measure the interval between a sky-earth transition and the following earth-sky transition. The measured time interval is recorded by punching a paper tape in a standard teletype format. The data thus recorded is later processed to determine the nadir angle of the satellite's spin axis corresponding to the earth-scan interval.

2. Performance Evaluation

The attitude-indicator subsystem performed satisfactorily throughout the evaluation period. A typical chart recording of TIROS VII attitude-indicator data is shown in Figure XIII-1.

C. NORTH-INDICATOR SUBSYSTEM

1. Function

The north-indicator subsystem provides electrical data for the determination of the satellite's orientation angle (i.e., the angle in the plane of the satellite baseplate between a zero-reference radial of the satellite and the bearing of the sun at the beginning of each picture) and thereby, the orientation of the transmitted TV picture. This data is transmitted to the ground stations by the TV transmitters. The satellite orientation data is used in conjunction with data from the ephemerides to determine the north direction in the pictures transmitted from the satellite.

The nine sun-angle sensor units form the first link in the data chain that provides data from which the north-direction of each TV picture can be determined. Each sensor unit consists of a solar cell behind a slit-type aperture in a special housing, with its sensitive surface perpendicular to a satellite radial. The units are mounted 40 degrees apart, around the vertical walls of the satellite housing.

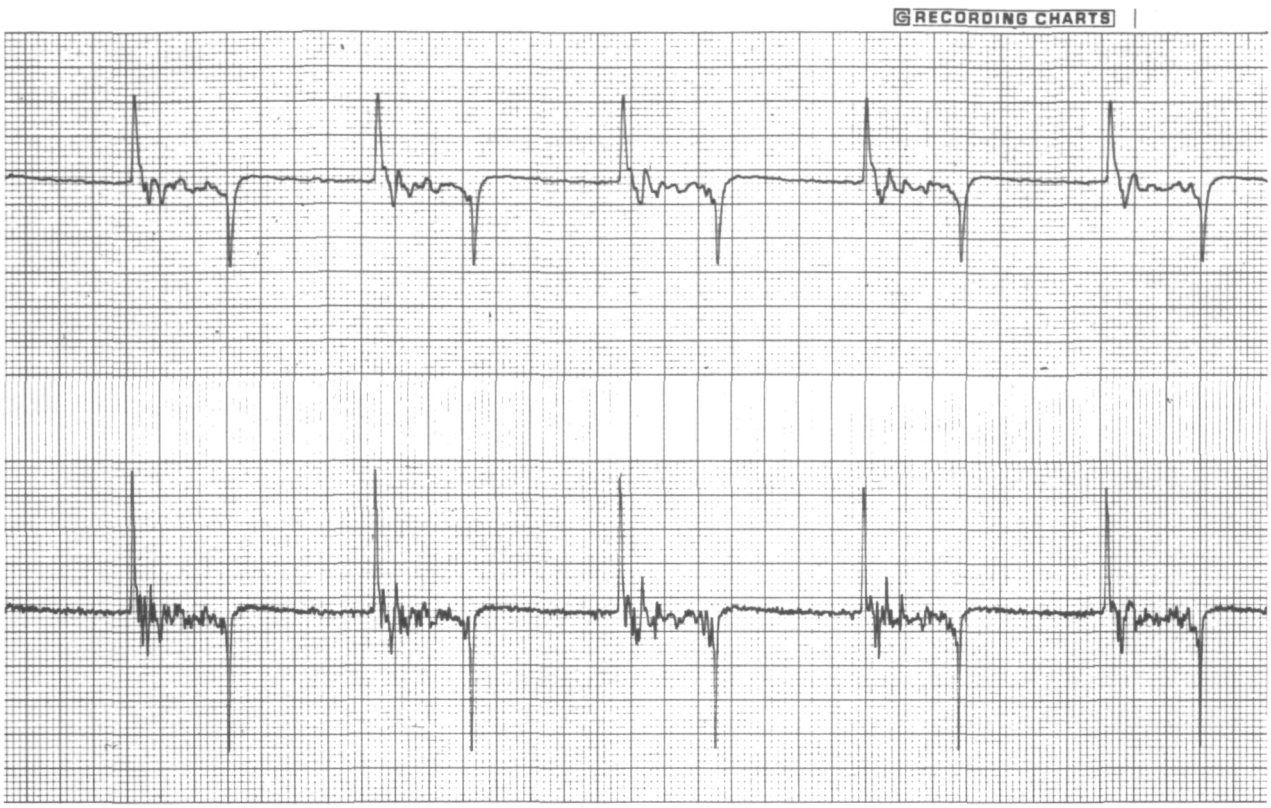


Figure XIII-1. Typical TIROS VII Attitude Indicator (H-1) Data

As the satellite rotates, the slits sweep across the direct rays of the sun, causing the sensor cells to generate sun-triggered pulses. These pulses trigger coded multivibrators located in the sun-sensor electronics package. Because of the sensor spacing and because of the 8- to 12-rpm spin rate, two of these coded pulses occur during each 2-second picture read-out. The coding of the multivibrator output pulses is sequenced in such a way that any two consecutive pulses uniquely define a sun-sensor location. These pulses are amplified, shaped in the sun-sensor electronics, and applied to the tape-recorder electronics.

In the tape-recorder electronics, the pulses are used to key a 10-kc subcarrier oscillator to provide 10-kc tone bursts with durations equal to those of the input pulses. If pictures are being taken in the remote mode (i.e., while the satellite is beyond the range of a ground station), the tone bursts are recorded by the tape recorder, along with the corresponding video information, and are stored until the satellite is commanded to play back. The tone bursts (along with the video information) are then "read back" into the electronics where the tone bursts are detected and again used to key the 10-kc subcarrier oscillator. The output of the oscillator is modulated on the TV carrier for transmission to the ground. When a sequence of direct pictures is being taken, the tone bursts are combined with the camera video subcarrier for direct transmission to the ground.

At the CDA ground station the sun-angle information is separated from the video signal by a bandpass filter. The tone bursts are then detected and applied to the sun-angle computer. The computer identifies the particular baseplate-referenced sun sensor associated with the coded sun pulses. It then relates the occurrence times of these pulses to the initiation of the video subcarrier, and computes the sun angle. The computed sun-angle data are displayed visually in binary form on the panel framing the kinescope and are photographed along with the video display. The north direction is then determined from the sun angle data appearing on the photograph and the orbital data corresponding to the time the TV picture is taken.

The basic requirements and the initial development and design of the sun-sensor electronics are described in the TIROS I final report.

2. Performance Evaluation

The north indicator subsystem has performed satisfactorily throughout the evaluation period. The pulse widths of the coded north indicator data are within allowable limits and the spacing of the pulses is accurate.

XIV. GROUND SUPPORT

A. LAUNCH SUPPORT

1. Launch Operations

In accordance with NASA directions, flight-model spacecraft F-7, prototype spacecraft T-2A, to Go, No-Go checkout van, and associated test equipment were shipped from AED on May 29, 1963. The equipment arrived at Cape Canaveral (now Cape Kennedy) on May 31, 1963, and was unpacked, inspected, and subjected to a complete electrical checkout by AED personnel. After these inspections and tests had demonstrated that no damage had been incurred during shipment and that the spacecraft was performing satisfactorily, the spacecraft was placed in the dust-free room to await the beginning of pre-launch testing.

On June 3 (Monday), the prototype spacecraft T-2A was removed from storage and delivered to Douglas Aircraft Company (DAC) for mating with the dummy third-stage rocket. The following day, the T-2A spacecraft/dummy third-stage combination was fitted to the launch vehicle on Launch Pad 17B for RF-interference testing. Because this was the first TIROS launching effort at pad 17B, it was necessary to make several minor wiring changes in the blockhouse to accommodate the TIROS spacecraft. These changes provided for charging of the spacecraft batteries and control of the fairing lamps. These changes were accomplished expeditiously and without difficulty. The RF interference tests were begun on schedule. During the tests, the spacecraft's transmitters were operated individually and simultaneously in various combinations. Receiving and demodulating equipments in the Go, No-Go van were used to monitor the spacecraft transmissions. Throughout the tests, there was no significant interference between transmitters, and the RF transmissions produced no serious effect on the launch-vehicle controls. Following the successful completion of the tests on June 4, the prototype spacecraft and dummy third-stage rocket were removed from the launch vehicle, separated, and returned to their assigned storage areas.

On June 5, calibration checks of flight-model spacecraft F-7 was begun. Calibration checks of the IR experiment were completed on that day and TV subsystem calibration checks were completed on the following day. The flight-model transmitting antenna was installed on the spacecraft and a complete electrical check was performed on June 7. Immediately following this check, the spacecraft was delivered to the DAC spin-balance facility. The spacecraft was weighed by DAC personnel (299.64 pounds) and the mechanical fit of the separation ring with the third-stage rocket was visually checked. The separation spring was omitted during this check. The mechanical align ment appeared to be excellent. No visible clearance existed between the mating surfaces.

After this preliminary visual check had been made, the spacecraft and rocket were separated and the separation spring was installed. The spacecraft was again mated

with the rocket and a runout measurement of the combination was made. The measured runout was 0.045 inch, considerably in excess of the 0.0075-inch runout of the satellite measured at AED on May 31, 1963. The mating surfaces were carefully inspected for alignment and a small alignment error was detected. After this misalignment has been corrected, a second runout measurement was made, yielding a value of 0.0099 inch. A special meeting was held on June 10 (Monday) to discuss the differing values of runout. It was agreed at this meeting that the magnitude of the difference indicated a possible misalignment of the spacecraft and rocket. Accordingly, the two were separated and the mating parts were inspected. This inspection revealed an improper fit between the separation-ring key and the spacecraft keyway. The keyway was enlarged and the mating check and runout measurement were repeated. The runout measurement was repeated several times and each time yielded a value of 0.0081 inch. This value was within the specified runout tolerance, and it was agreed that successful mating could now be achieved.

Balancing of the third-stage rocket and spacecraft combination was begun on the afternoon of June 10 and completed on June 11. On June 12, the combination was transported to Launch Pad 17B and mated with the second stage of the launch vehicle.

On June 13, the scheduled Task 4 and F-minus-3-days tests were performed with satisfactory results. On the following day a checkout test of the IR experiment indicated a possible instability of the channel 4 voltage-controlled oscillator (VCO). However, additional testing was performed without further indication of instability of the VCO.

Spacecraft testing was resumed on June 17 (Monday). The F-minus-1-day procedure was advanced by two hours to eliminate a range conflict with another program. Spacecraft checks were completed on schedule and all systems operated normally. The protective coating was removed from the mirrors for the omnidirectional IR experiment and the electron temperature probe was secured to its mount.

On June 17, at 1755 hours, the launch-day procedure was initiated. Spacecraft checks were performed with the protective fairing removed. The third-stage blast shield was installed around the rocket and a final inspection was performed to ensure that all of the protective covering had been removed from the spacecraft. Installation of the fairing was begun and proceeded until one of the four explosive bolts snapped as it was being tightened. The final spacecraft check with the fairing in place was performed satisfactorily, after which the broken bolt was replaced. However, the replacement bolt also snapped at the rated torque level. A hold was placed on the launch procedure to permit evaluation of this difficulty. At approximately 0350 hours on June 18, the launch was postponed and rescheduled for 0450 hours on June 19. Because the decision to postpone had come before the oxydizer had been pumped into the first stage, the launch vehicle remained fueled, but without the oxydizer. The cause of the breaking of the bolts was found to be associated with the finish used. The bolts were cadmium-plated while, on previous launch vehicles, nickel-plated bolts had been used. When the nickel-plated bolts were tightened to the proper value of torque, they remained intact, and no further problems were encountered.

The hold was lifted and the launch day (F-minus-0) procedure was initiated at 2145 hours on June 18. The spacecraft checks were repeated with good results. The beacon transmitters were turned on at 0410 hours EST on June 19. A brief direct-mode check of the TV cameras was made using the fairing lamps as the illumination source. The terminal count was started at 0415 hours and continued to ignition at 0450 hours. All of the launch vehicle stages performed normally, although the thrust of the first stage was slightly less than nominal. Separation of the satellite from the third-stage rocket was observed at 0511 hours and 13 seconds (EST) and de-spin was observed at 0515 hours and 45 seconds (EST), both observations being made by the Winkfield, England, Minitrack station.

2. Orbital Data

The satellite spin rate at injection was 128 rpm. After de-spin, the rate was 8.33 rpm. The satellite entered a nearly circular orbit with an apogee of 403.3 statute miles and a perigee of 385.9 statute miles. The orbit was inclined to the equator at 58.2 degrees. The period of orbit was 97.4 minutes.

B. COMMAND AND DATA ACQUISITION STATIONS

1. Introduction

Three primary Command and Data Acquisition (CDA) ground stations are included in the TIROS VII ground complex. These are located at the Pacific Missile Range (PMR), with installations at Point Mugu and San Nicolas Island; at Wallops Island, Virginia; and at Gilmore Creek, near Fairbanks, Alaska. A secondary CDA station, located in the AED facility near Princeton, New Jersey functions as a back-up station for the primary Wallops Island station and as the base for AED engineering evaluation of the satellite. All of the CDA stations, primary and secondary, consist of four basic sections as follows:

(1) satellite command and control equipment,

(2) data-receiving components,

(3) data processing and display components, and

(4) recording devices.

The functions of the primary CDA ground stations are as follows:

(1) to transmit radio signals to the satellite for programming its operation and data transmission,

(2) to receive signals carrying the television, attitude, and telemetry data from the satellite,

(3) to extract data from the carrier signals,

(4) to record and identify the received data, and

(5) to relay the recorded attitude and telemetry data, along with station status reports, to the TIROS Technical Control Center, GSFC, Greenbelt, Maryland.

The back-up CDA station at the AED facility is equipped with the same functional units as the primary stations. This station monitors the responses of the satellite to commands from the Wallops Island station and tracked the satellite during the first 7 days following the launching of TIROS VII. In addition, it is used, as required, to interrogate the satellite for obtaining engineering evaluation data.

2. Operational Evaluation

a. General

The operational performance of the ground stations during the evaluation period was generally good. The heavy programming load imposed on the ground stations by the simultaneous operation of three satellites was further increased by the curtailment of the PMR stations operations starting on March 19, 1965. On April 13, the PMR station permanently ceased operations, and all programming was transferred to the Wallops Island and Alaska ground stations. In spite of this increase in work load, the ground station personnel continued to perform their functions effectively.

RCA's contractual responsibility for the operation and maintenance of the Fairbanks and Wallops stations terminated on December 31, 1965. NASA has transferred this responsibility to the data acquisition facility. RCA's personnel support of the ROE operations at Suitland, Maryland, also terminated on December 31, 1965, per contractual agreement.

b. Wallops Island Ground Station

Before the TIROS VII launching, the Wallops Island ground station was rechecked for operational readiness. The station had been actively engaged in tracking TIROS VI and all systems except the IR system had been in regular service. Supplies were checked and replenished as necessary. Because TIROS VII is equipped with the NASA IR capability, extensive recalibration and realignment of the IR ground equipment was performed and retraining of the station personnel was undertaken to familiarize them with operation of the IR equipment. TIROS IV tapes containing composite IR data were used for this purpose.

The tracking of the satellite during the launch phase proceeded as planned, and the ground systems performed well. During the first few orbits, lack of accurate ephemeris data precluded the use of the antenna programmer and some difficulty was experienced in maintaining accurate tracking.

In an attempt to achieve greater accuracy in the setting of the satellite clocks, an ITA 1.5-kw transmitter was used in place of the Collins transmitter. Due to the proximity of the command-antenna array and the beacon array, severe interference occurred in the high-frequency beacon circuits. A modified low-pass filter was installed on the ITA output to alleviate the interference problem.

Because of tracking problems with the high-gain antenna, the medium-gain antenna system was used almost exclusively during the early interrogations of TIROS VII, with satisfactory performance. However, when this system was in use, it was not possible to change frequency rapidly. As a result, even though the TV signal could be tracked satisfactorily, the system would not lock onto the IR signal when the satellite's TV transmitters turned off. In turn, this caused dropouts in the IR Brush record, which hindered data analysis.

Representatives of NASA and AED visited Wallops Island on July 11, 1963 to review station operations. Some inadequacies in the antenna systems were observed and a course of action for overcoming these inadequacies was formulated. AED engineers visited the station on July 22, 23, and 25 to check out the delay clock-set procedure for TIROS VII and to instruct local personnel in the type of programming that had been devised to improve clock setting accuracy of the satellite. (The programming procedure is described in the evaluation of the instrumentation control subsystem in this report.) The use of this programming procedure resulted in an immediate improvement in clock setting accuracy.

The station continued to operate satisfactorily during August 1963, and effective programming was achieved using the Collins command transmitter. Although, for one brief period, a problem in the photographic processing at this station resulted in an erroneous report of degradation in the quality of TIROS VII pictures, this problem was quickly remedied and no further difficulties were experienced.

The refurbishment program continued, with the delivery and installation of tape recorder decks. A data box containing a new Bulova timer was supplied to the station, to give a more accurate real time indication on the monitor presentation panel than had been obtained from the clock used previously.

Minor problems were experienced with the General Bronze antenna on September 21 and 27. Repairs were quickly effected and the antenna was placed back in service on each occasion without interruption in scheduled interrogations.

A building reconstruction program at the site was started during October 1963. Despite the broad scope of the work undertaken, TIROS VII interrogations continued without interruption.

Only one interrogation was cancelled during October because of antenna malfunction. This cancellation occurred on October 4, when the Kennedy antenna failed to operate. However, the problem was quickly overcome and the station was operative for the next scheduled interrogation.

Building reconstruction continued through November. Major modifications to the General Bronze antenna were started on November 4. The work was completed and the antenna was returned to operational status before December 10. While the General Bronze antenna was being modified, the station remained operational, using the medium-gain antenna system for data reception. Data received through the use of the medium-gain antenna contained a higher-than-normal noise level but, for the most part, was usable for meteorological purposes. The 136-Mc Kennedy antenna underwent scheduled maintenance during the period from November 12 to November 16. The station was inoperative during this period.

All ground station systems at the Wallops Island station were checked and recalibrated during early December in preparation for the TIROS VIII launch. Checks were made on the following items of equipment: Collins transmitters, master clock, sawtooth and deflection amplifiers, TV monitor scope, sun-angle computer, Berkely counter, command-tone generator, tape degausser, signal generators, TV combiners, Sanborn recorders and beacon receivers. Sufficient time was available before the launch to check out the new drive system for the General Bronze antenna. The new system provided a substantial improvement over the previous drive system. However, difficulties were experienced with the drive system during January, and the antenna was removed from service on four occasions.

Commands transmitted to operating TIROS spacecraft from the station were placed under surveillance during the period from January 10 to January 13, for the purpose of evaluating command effectiveness, particularly of the clock-set command. All transmissions during this period were monitored and recorded for further study.

The antenna programmers were moved from the TIROS racks and reinstalled with antenna-control equipment on the second floor of the ground station. The General Bronze antenna was removed from operation on March 11, 1964 to permit servicing of the drive system. Maintenance work was completed on March 14, and the antenna was returned to operation on that date. Additional maintenance work was performed on the elevation drive system on March 25, without removing the antenna from service.

The General Bronze antenna was removed from operation on April 9, 1964 for repair and recalibration. The required work was completed and the antenna was placed back in operation on the following day. However, because its performance was still unsatisfactory, the medium-gain antenna was used throughout the remainder of the month. As had previously been the case, the use of the medium-gain antenna resulted in a higher-than-normal noise level; however, the TV pictures received at the Wallops Island station were meteorologically useful. The General Bronze antenna was returned to service after completion of repairs and adjustments on May 4. It was again removed from service temporarily on May 15 and restored to regular service on the same day.

During the period from June 21 to 28, operations were suspended to allow wiring changes to be made to accommodate the dual-TIROS Wheel configuration satellite. This work was completed on June 28, and the station was immediately returned to operational status.

RF interference in the 136-Mc band was experienced throughout August 1964; however, only on August 28 was this interference severe enough to cause loss of telemetry and attitude data.

During August, the communications equipment was relocated from the ground-station area to the newly completed, telemetry building annex. This relocation provided additional room within the ground-station area for work benches and test equipment.

Also during August, RF interference from local sources continued to affect data received from the satellite. On September 4, 5, and 6, TIROS VII telemetry and IR data was unusable because of RF interference. On September 11, 12, and 13, telemetry data from TIROS VII was unusable because of noise on the beacon signal. On September 24, picture data from TIROS VII contained RF interference from an unknown source.

High winds in the Wallops Island area on September 22 made it necessary to "stow" the General Bronze antenna. However, wind velocities were not so high as to prevent operation with the medium-gain antenna.

On October 1, a new contractor assumed responsibility for operation of the antenna systems at the Wallops Island CDA station. A number of the personnel assigned to the station were unfamiliar with station operations and substantial difficulty was experienced in tracking the satellites.

On October 8, the General Bronze antenna was removed from service because the amplitude of received signals appeared lower than normal. Investigation revealed that water had leaked into the coaxial cabling. A considerable amount of time was required to locate and correct the leaks in the cabling and, while this effort was underway, the medium-gain antenna system was used for satellite tracking. Because of the lower gain of this antenna system, many of the pictures received exhibited a comparatively high noise level. On October 14, the General Bronze antenna was returned to service. High winds on October 17 made it necessary to stow the antenna during one scheduled pass.

On October 26, the General Bronze antenna was removed from service for final repairs.

The inexperience of the new ground station personnel was evident throughout November. The rate of tracking difficulties and operational errors remained comparatively high. However, the quality of the photographic work improved considerably during this same period.

Local radio frequency interference (RFI) affected TV, IR and telemetry data during November. During that month, local RFI measurements were conducted at Wallops

Island in connection with a comprehensive study of RFI in the general area. Reference signals generated for this study affected TIROS TV data on November 13 through November 15. The quality of photographic processing at the station remained high during November.

The general performance of the Wallops Island station was very good during December, 1964. During this period, this station had the best record of the three CDA stations for accurate clock sets. The quality of photographic processing remained high during December.

From January 2 to January 7 the medium-gain antenna system was used because of a failure in the hydraulic drive system of the General Bronze antenna. As previously, the use of the medium gain antenna systems resulted in noise on much of the TV data, and, in some instances, in unusable data. On January 25, 1965, the 2-kw ITA transmitter and the APT Helix antenna were put into service, and on January 27, both the General Bronze Antenna and the Kennedy antenna were removed from operation for service and repairs. These antenna systems were returned to service on February 13.

The General Bronze antenna was again removed from service (for 4 hours) on April 7 and, beginning April 12, for 2 days. Also during April, TV data was lost due to inaccurate ephemeris data which caused tracking difficulties. On April 15 and April 18, difficulties in the TIROS-unique equipment resulted in loss of TV data. Severe radar interference experienced in mid-April was attributed to the Naval operations in the area.

The General Bronze antenna was removed from service for repairs from May 10 to May 15. The medium-gain antenna was used with a resulting increase in noisy and unusable TV data.

During June, the performance of this station was generally good. There were some instances of loss of pictures or non-occurrence of remote sequences due to noise or interference, operational errors, and antenna-equipment difficulties. On June 28, the General Bronze 235-Mc antenna was removed from service due to difficulty with the elevation-drive system; however, it was corrected and returned to service later the same day. During the last week of June, some problems were experienced with high-beacon reception from the Kennedy 136-Mc antenna. The trouble was attributed to the coaxial switch, and it was replaced on June 30.

During August, the daily operational assignments were conducted on a satisfactory basis, except that severe local RF interference on the beacon frequencies was observed during the first 10 days of August. The General Bronze receiving antenna was removed from operational status on August 7 because of a malfunction in the azimuth drive system. Necessary repairs were completed, and the unit was returned to service within 8 hours.

The Wallops Island station experienced tracking and antenna difficulties on ten occasions during September, 1965. In addition, on five occasions, difficulties with the TIROS-unique equipment accounted for the loss of some TV and telemetry data.

TIROS VII CDA operations were conducted on a generally satisfactory basis during October, November, and December, 1965. However, tracking difficulties resulted in the loss of some TV data on five occasions and telemetry data on three occasions.

c. PMR Ground Station

Although the PMR ground station had been in use for regular interrogations of the TIROS VI satellite, the facilities were rechecked before the TIROS VII launch date to ensure operational reliability. Command address kits, previously received and installed, were rechecked to ensure the station capability for addressing command messages to TIROS VII. Because IR facilities at PMR had not been used since the TIROS IV program, considerable time was devoted to appropriate IR checkout procedures. New personnel not familiar with handling IR data were given special training in the operation of the equipment; in addition, instructions were given in the proper handling and interpretation of IR data to be received from the new spacecraft.

At launch time, the station was operational and prepared for carrying out all command and data acquisition responsibilities as dictated by the requirements for the TIROS VII spacecraft. After TIROS VII was successfully launched and injected into orbit, the PMR station demonstrated its capability by effectively commanding and acquiring data from the satellite. Inaccurate ephemeris data resulted in some difficulty in tracking during the first two days. It was desirable at the time to use the antenna programmer rather than the auto-track system which, through the nutator, introduced a severe 10-cps modulation on both the TV and IR signals. Simultaneous fading noted on the agc paper-tape recording for the IR receivers was found to have been caused by improper patching of these receivers to the horizontal and vertical multicouplers. The problem was eliminated when the receivers were repatched to their respective multicouplers for diversity operation.

Difficulties with the command transmitter, feed cable, and command antenna were experienced during the early orbits of TIROS VII. To alleviate these problems, it was recommended that the ITA transmitter be replaced with a new unit and that the command antenna be removed from the periphery of the AT-36 dish, remounted on a separate pedestal, and slaved to the AT-36 drive.

On July 26, the TIROS Technical Control Center directed PMR to follow the delayed clock-set procedure for TIROS VII interrogations. Station personnel responsible for programmer operation handled the required automatic-manual procedure very effectively.

A new photographic van was installed and placed in operation during the early part of July. In mid-July, AED shipped a government-furnished densitometer (MacBeth, Model TD-100) to PMR at the request of NASA. This unit was one of the three units supplied in connection with the accumulation of test equipment for the Alaska ground station.

During September, this station was troubled by radar interference from naval units operating in the vicinity of San Nicolas Island and by radio interference from the general direction of Los Angeles. Installation of a new data clock for the TV monitor panel time display was completed during September.

On November 12, the AT-36 antenna was temporarily removed from service for repair of command and beacon transmission cables which had been accidentally severed; operation was interrupted again on November 29 for installation of a rotary joint.

A thorough check of all systems was completed during early December and, by December 5, 1963, the station was in complete readiness for the forthcoming launch of TIROS VIII.

Radar interference continued to be a problem during January. Interference occurred frequently when naval operations were conducted near the San Nicolas Island site.

A new antenna/command van was received at San Nicolas Island during March. The new van provided a separate mount for the command antenna and eliminated the cabling problems which had been encountered frequently while the command antenna was mounted on the periphery of the 60-foot reflector. The new transmitter van was completely wired and the two command transmitters installed and checked out during April.

On May 20, a drive belt in the AT-36 nutator assembly broke, causing the loss of auto-track capabilities. High winds prevented repairs until May 22. During this period, the antenna programmer was used, permitting satellite tracking operations to continue.

Substantial radar interference was again experienced during the period from June 10 to 15, but picture usability was not significantly impaired. Radar interference was observed on data received from TIROS VII on July 1 and 2.

A new, government-furnished equipment van was installed on San Nicolas Island on August 21, and the TIROS station was removed from operation to permit relocation of the equipment to the new van and modification of the equipment for the TIROS Wheel program. This effort was completed on August 31.

The microwave link used to transmit data from San Nicolas Island to Point Mugu caused serious fades in the signal level of transmitted data during August. In early August, the effectiveness of data transmission degraded to such a degree that data had to be retransmitted a number of times before a complete sequence of pictures could be obtained. Problems related to the microwave link (between the San Nicolas Island site and the Point Mugu site) received attention from cognizant Navy groups during September.

In the early part of October, the two digital command programmers (required for TIROS IX) were installed in cabinet racks mounted in the new van located at San Nicolas Island. The station was relieved from routine interrogation schedules during the period from October 6 to 8 to enable installation and checkout of the programmers and training of personnel.

Some improvement in operation of the microwave link between San Nicolas Island and Point Mugu was noted after repairs to the link were effected by cognizant Navy agencies. However, some degree of signal fading continued to be evident when adverse atmospheric conditions were present. The microwave link continued to be a limiting factor on performance at this site. The Navy also began using the TV channel for other operations, causing conflicts with TIROS schedules.

During December 1964, the PMR ground station operated in a very satisfactory manner. Only one minor equipment difficulty was experienced which required the adjustment of a horizontal sync separator in the ground station equipment.

On January 9, 1965, a break in the nutator belt of the AT-36 antenna prevented the use of the antenna for automatic tracking. The cause of the problem was corrected in 36 hours. On January 23, the PMR station experienced a loss of command capability because of a faulty antenna rotary joint. A suitable replacement was not available until February. To circumvent this problem until a replacement for the rotary joint could be obtained, the command transmitter was connected to the antenna by coaxial cable and the station returned to operation on January 25.

On February 3, the new rotary joint was installed on the AT-36 antenna, but the PMR ground station still experienced command difficulties. Investigation revealed that moisture had accumulated in the new rotary joint, as it had in the old one. The new rotary joint was removed and the coaxial cabling reinstalled. The new joint was disassembled and cleaned and reinstalled on the antenna by February 13, after which normal operation was resumed.

By direction from NASA on March 19, the PMR ground station operations were curtailed in preparation for complete discontinuance of operation by April 14. The station ceased operations one day early, on April 13. The ground station equipment was shipped to AED early in May.

d. Fairbanks, Alaska, Ground Station

Command and data acquisition operations at the Fairbanks station were commenced, on a limited basis, on September 2, 1963. During this initial effort, TIROS VII was interrogated on two orbits, but interference from the command transmitter caused some of the TV data to be noisy and unusable. On September 7, filters were installed between the antenna and the TV preamplifiers which greatly reduced the amount of interference. This station successfully undertook the interrogation of TIROS VII on September 10, and the AED-furnished equipment was, as of that time, considered to be fully operational. However, the overall station was still undergoing engineering evaluation and was used to interrogate VII only on a limited basis, in accordance with scheduling from the TIROS Technical Control Center.

Command transmitter problems at the Alaska ground station became critical during the first week of October, 1963. The outputs of both ITA transmitters were found to

contain audio modulation even though no control tones were applied to the transmitter. This problem was remedied by the installation of a Collins 200-watt transmitter on October 8. All systems of the TIROS-unique ground equipment performed satisfactorily.

Antenna problems at the Alaska site caused the cancellation of three scheduled interrogations on November 19 and three more interrogations on November 20. These problems were reported to have been caused by failure at low-temperature of antenna system connectors. Operations at this ground station were adversely affected by local atmospheric disturbances (aurora borealis) during January 1964. Deep fades on both the TV and the IR carriers were observed during an aurora display on January 18. During early March, command-frequency interference was detected in the television, horizon-scanner, and telemetry data. Immediate investigation into this problem revealed a defective cable between the transmitter and antenna. The replacement of this cable on March 3 eliminated the interference problem.

Although earth tremors occurred in the Fairbanks area during the Alaskan earthquake on March 27, the Fairbanks ground station was not damaged.

An 85-foot antenna installed at the Weather Bureau site (GILMOR) was placed in service) with the Fairbanks CDA station on May 19. This antenna was used for approximately one month during modification of the antenna at the CDA (ULASKA) site. The control system for the temporary antenna required operating procedures which differed considerably from those used with the CDA (Ulaska) station antenna. As a result, some tracking difficulty was experienced during the last part of May. However, by the end of the month, operational errors diminished as personnel became familiar with the requirements of the substitute system.

Satellite interrogations by the Fairbanks station were cancelled or rescheduled to other ground stations on June 1 and 9, and on June 11 through 14, because of damage to the main cable running between the ULASKA and GILMOR sites. (On May 31, a contractor performing work not associated with the TIROS program cut into the cable. Although the nine Styroflex conductors were damaged extensively, three of them were still partially usable, and two were used for limited TIROS operations until June 15, when emergency repairs were completed and normal cable use was restored.)

During July, a number of scheduled interrogations of TIROS VII were cancelled to permit the use of the Alaska facility in support of the Nimbus program. On July 15, after command difficulties had been experienced for several days with both TIROS VII and TIROS VIII, a coaxial switch (used to connect the transmitter RF output to the command antenna or to a dummy load) was found to be defective. The malfunction prevented connection of the transmitter to the antenna.

Modifications to the ULASKA antenna were completed during July. On July 28, use of the GILMOR antenna at this station was discontinued, and use of the ULASKA antenna was resumed. During the first 10 days of August, the TV carrier amplitude received at

the Fairbanks station appeared to be abnormally low, and the recorded TV signals showed simultaneous fades in both the horizontal and vertical components. This problem was not experienced by other Command and Data Acquisition (CDA) stations, and it was, therefore, considered a local station problem. An investigation was started on August 10, when the station was shut down to permit installation of digital command programmers. This investigation revealed that, during the antenna modifications performed by the cognizant Data Acquisition Facility (DAF) personnel, the cables between the summing "T" for the horizontal and vertical dipoles and the hybrid ring had not been cut to the proper lengths. After correction of the cabling problem, the TV signals were received and recorded without difficulty.

TIROS operations at the Fairbanks CDA ground station were interrupted frequently during the period between September 1 and September 15, while the station was being utilized for launch support for Project OGO and back-up support for the Nimbus operations. During this period, the Packard-Bell computers used to record program tapes for both the TIROS and Nimbus antennas at the Fairbanks station were found to be inoperative. A back-up method of transmitting program tapes directly from the Goddard Space Flight Center by means of Digitronics Systems was employed, but the results were less than satisfactory. The necessary repairs were initiated on the Packard-Bell Computers.

It was observed that the signal level received using the GILMOR antenna during October was lower than that received using the ULASKA antenna; the use of the GILMOR antenna accounted for much of the noisy TV data received at the Fairbanks station in October. When the ULASKA antenna was in use, the station TV signal was at the normal level and resulted in satisfactory pictures.

During November, a number of difficulties were encountered, and the station's effectiveness dropped below the performance levels established previously. These difficulties included antenna system difficulties, operational errors in connection with both the TIROS equipment and the antenna system, and TIROS equipment malfunctions.

During December, station performance improved considerably. From December 7 to December 16, station operations were suspended while the CDA station equipment was moved from the ULASKA site to the GILMOR site. Normal station operation was resumed on December 16, after this move had been successfully completed. The Fairbanks ground station experienced antenna difficulties due to an extended period of low temperatures on December 24 and December 25. Difficulties were experienced in accurately setting clocks during the last part of December; however, normal operation was restored before the end of the month.

Between January 1 and January 4, 1965, the Fairbanks station encountered command interference and some telemetry data was unusable. On January 11, the GILMOR site antenna was removed from operational status for repairs, and the ULASKA site antenna system was placed in operation. The GILMOR antenna was returned to service on

January 16, but was removed from service again, from January 24 to January 30. In an effort to reduce command interference, a separately mounted antenna was put into service on January 25; however, transmitter interference was noted on both the beacon and TV frequencies on January 29 and 30.

During February, the GILMOR facility at the Fairbanks station was used to perform the largest percentage of TIROS interrogations. Despite the increased load, the facility performed effectively, without significant loss of data. During the early part of February, the photographic negatives developed at GILMOR were of low but uniform contrast. Investigation revealed that the chemicals used in the water-treatment system were retarding negative development. The problem was eliminated by using distilled water.

During March, the performance of the Fairbanks station was good with very little loss of data. The antenna systems performed satisfactorily and station operational procedures were good.

Loss of data during April was less than during any preceding month. Some difficulties related to the antenna and data transmitters were encountered during April, with some of these difficulties resulting from inaccurate antenna predictive data.

Transmitter and antenna difficulties caused loss of command or program delay on seven occasions during May. A tracking-schedule error caused loss of TIROS VII data on May 19. Photographic negatives and prints processed at the GILMOR facility continued to be of good quality and well within TIROS specifications.

The performance of this station during June was generally good. There were some instances of loss of picture or non-occurrence of remote sequences; these instances were due to noise or interference, operational errors, and antenna-equipment difficulties.

All operations were conducted on a satisfactory basis throughout July. Starting on July 8, this station participated in phase 2 of the Remote Operation Experiment (ROE) by transmitting TIROS TV data to U.S. Weather Bureau at Suitland, Maryland, over the existing wideband communications link.

TIROS VII CDA operations at this station continued without interruption during August; however, minor antenna difficulties affected the operation on August 24. On August 23, the GILMOR antenna was removed from service for repairs and calibration. Because of difficulties with the ITA transmitters and associated transmission lines at the higher output rating, command to TIROS satellites was transferred on August 27 to the 5-kw transmitters and Satan antenna at the new Rose Creek command site. Performance of the new command facilities was satisfactory through the remainder of August.

The Satan 5-kw transmitter command system was used to command TIROS VII throughout September, except during the period from September 17 to 23, when the

ITA transmitters were used. During that period the Satan system was removed from operational status for maintenance and system check-out purposes.

Operations during October were conducted in a very satisfactory manner, and loss of data due to station operations was minimal. Repairs and recalibration of the GILMOR 85-foot receiving antenna were completed on October 4, and the antenna was used for satellite interrogation on that date. However, difficulties developed in the Y-axis drive system which necessitated additional repairs and a further shut-down of the antenna. These repairs were completed, and the unit was returned to operational status on October 7.

The minor TIROS operational and equipment difficulties experienced during November are partially attributed to new personnel at the ground station. However, as these new crew members gained experience, the difficulties decreased.

Under phase 2 of the ROE project, all TV data was transmitted over the wideband data link to the Environmental Science Services Administration (ESSA), during December. On December 2, the 85-foot receiving antenna at GILMOR was damaged and was taken out of service until December 6. Normal operations were continued during this period using the ULASKA antenna facilities.

e. Princeton Ground Station

In preparation for launch support of TIROS VII, the Princeton backup ground station at the AED facility conducted two practice interrogations of TIROS VI on June 10, 1963. Both interrogations were performed in a highly satisfactory manner. During the pre-launch period, supplies at the ground station were replenished and several replacements were made. A new, short persistence kinescope was installed in the TV monitor.

The Princeton station was operational and ready at the time of launch and acquired the TIROS beacon transmissions approximately two minutes after the launch, just before second-stage ignition. Both beacon channels became noisy for a brief period as the second-stage engine started. Strong beacon signals were being received at the time of spin up of the spacecraft and third-stage rocket and the Princeton station determined the spin rate to be 128 rpm. As was expected, the beacon signals had faded before the spacecraft and third-stage separated.

The Princeton station acquired the satellite transmissions on the first orbit. Both the TV and the IR transmitters were operating, having been tuned on by command from the PMR ground station. The initial pictures received at the Princeton station during this first orbit were of good quality, although noise was present in the TV and IR data because of the distance of the satellite from the ground station. When the satellite was commanded by the Wallops Island station on this same orbit, the signal quality improved. The telemetry and attitude data received during the first pass were of good quality and it was possible to determine that the satellite's spin rate was 8.3 rpm.

The station was scheduled to perform the East Coast interrogation on orbit 3 but was given permission to cancel because of the uncertain accuracy of the ephemeris data. The Princeton station performed a backup interrogation of TIROS VII on orbit 15 (still on June 19) when antenna problems at the Wallops Island station forced that station to cancel its scheduled interrogation. The interrogation on orbit 15 was prevented from being entirely satisfactory by difficulties in establishing telephone communication between the two ground stations. However, on orbit 18, when the Princeton station performed a regularly scheduled interrogation, very good results were obtained. Ephemeris data received late on June 19 proved very satisfactory and were used with good results until the afternoon of June 21.

In general, the launch support operations performed by the Princeton station from June 19 through June 26 were very satisfactory, especially from the standpoint of permitting evaluation engineers an immediate awareness of satellite performance.

The ground station at the AED facility was placed in operation on July 2 and 3, and on July 17 and 18, to conduct performance evaluations of the command sensitivity of TIROS VII. During these periods, the station was used to (1) measure RF sensitivity of the satellite's command receivers and (2) determine the sensitivity of the satellite's clocks to clock-set commands.

During a prepass antenna checkout on October 12, 1963, a fracture of the elevation drive shaft caused the antenna assembly to hit the mechanical stops, resulting in damage to the 136-Mc ground planes. Repairs were started on October 14. The antenna was repaired and returned to service on November 4. AED passively tracked and acquired data from TIROS VII on November 6 (orbits 2076 and 2077), November 7 (orbit 2090), and on November 8 (orbit 2102). These passes were all commanded from the Wallops Island ground station. The AED ground station assumed command and interrogated TIROS VII on November 14 (orbit 2194), on November 21 (orbit 2296), and on November 22 (orbit 2310). The data from these interrogations were used in an engineering study of the clock-set capability of system No. 2 and for an evaluation of spacecraft load-bus voltage under varying load conditions.

Work on the TIROS General Bronze antenna, which had begun in advance of the other ground station preparations for the TIROS VIII launch, was interrupted on December 10 when a fracture of the azimuth drive shaft was discovered. The shaft had apparently sheared under the normal stresses of operation since no high winds were experienced during this period. Immediate action was taken to remove and repair the shaft and to restore normal operation in the shortest possible time. Reassembly of the drive system was completed on December 13 and the antenna was used later on that day to track TIROS VII. Antenna and RF operations following this repair were exceptionally good.

Other work on the TIROS equipment accomplished during this period included the removal of all power supplies for preventive maintenance and recalibration, maintenance of the van air conditioning equipment, realignment of the attitude selector and monitor systems, and modification of the video calibrator. Work on the power supplies was

completed on December 5, at which time the equipment was shut down for maintenance of the air conditioning system. This work was completed on December 11. The video calibrator was modified to permit video modulation of an RF generator located in the antenna van, after which both the RF system and the video system could be checked in the same operation. Realignment of the attitude selector and monitor was completed on December 13.

At NASA's request, TV system calibration tapes for distribution to the CDA ground stations were made by duplicating the Princeton station calibration tape used in pre-launch calibration of the satellite cameras. The tapes were completed on December 13.

C. TIROS TECHNICAL CONTROL CENTER

1. Function

NASA Operations Division, Goddard Space Flight Center, Greenbelt, Maryland, functioned as the TIROS Technical Control Center (TTCC) for the TIROS VII satellite. The duties and responsibilities of the TTCC were as follows:

(1) to accept, analyze, and catalog engineering reports on satellite and ground station conditions;

(2) to accept, analyze, and transmit predictions concerning the locations of areas suitable for taking pictures, and the times when the satellite could be contacted by the ground stations;

(3) to accept daily programming recommendations from the U.S. Weather Bureau;

(4) to decide the actual sequence of operations for each day, after taking into consideration the condition of the power supply and the performance of the satellite and ground stations;

(5) to prepare and transmit specific operating instructions and pertinent acquisition and picture-orientation information to the ground stations;

(6) to accept and review performance reports and significant telemetry data from the CDA stations;

(7) to select and transmit, immediately, instructions required for handling emergency situations; and

(8) to coordinate all TIROS VII operational phase activities.

2. Performance Evaluation

TTCC performed its assigned functions very effectively throughout the period evaluated. Through its direct communications link with the ground stations, TTCC followed spacecraft operations, orbit by orbit, whenever problems developed. Critical problems or emergencies were reported, as observed, to responsible NASA and AED personnel by commercial telephone. Calls were routed to the offices and, in some cases, to the homes of the individuals concerned. The excellent working relationships between TTCC, the CDA stations, various NASA groups, and the AED engineering and ground station personnel, established in the past, was maintained throughout this evaluation period.

APPENDIX A
EVALUATION TESTS OF TIROS .3KS5 SPIN ROCKETS

1. GENERAL

The evaluation tests described in this appendix performed as a consequence of the low increases in spin rate of TIROS VII on orbits 355 and 1809 and of the nutation analysis of orbit 355, which showed that the changes in spin rate, the momentum, and nutation angle on orbit 355 were all consistent with the firing of a single spin-up rocket instead of the pair that is normally fired in response to a spin-up command. Sixteen of the .3KS5 rockets were tested. The primary purpose of the testing was to determine the degradation, if any, that resulted from the rockets being stored for over a year following their manufacture. The firing tests also provided other information pertaining to rocket performance, including the effects of resistance mismatch on rocket performance, the magnitude of current drain during firing (as a measure of circuit performance), the effect of temperature on rocket performance, the effect of subjection to environmental qualification testing on rocket performance, and the probability and effect of rocket exhaust gases being deposited on the camera lenses.

2. TESTS

Test firings were performed by mounting pairs of rockets on the inertia wheel shown in Figure A-1, and, with one exception, the rocket pairs were fired with the inertia wheel stationary. (In the one exception the rockets were fired when the inertia wheel was spinning at 138 rpm.) Also mounted on the inertia wheel were glass slides positioned to collect exhaust material from the rockets and a tachometer, to provide an output voltage proportional to the speed of rotation. The complete test set up is shown in Figure A-2. The TIROS rocket switch and rocket command detection circuit were used to initiate firing of the rockets. An audio exciter simulated the command tone. The tachometer output, a voltage proportional to the rocket firing currents, and a voltage proportional to current flowing in the detector circuit were monitored and recorded by an oscillograph. The tachometer output was also recorded on magnetic tape, as were the voltage step that occurred in the firing circuit when the rocket switch was operated, and audio signals from a microphone placed near the rockets.

For the cold temperature tests, the rockets and the inertia wheel were cooled by exposure in a (Tenney) temperature chamber at -25°C for 24 hours. During cold temperature testing, it was found that the performance of the tachometer was affected by low

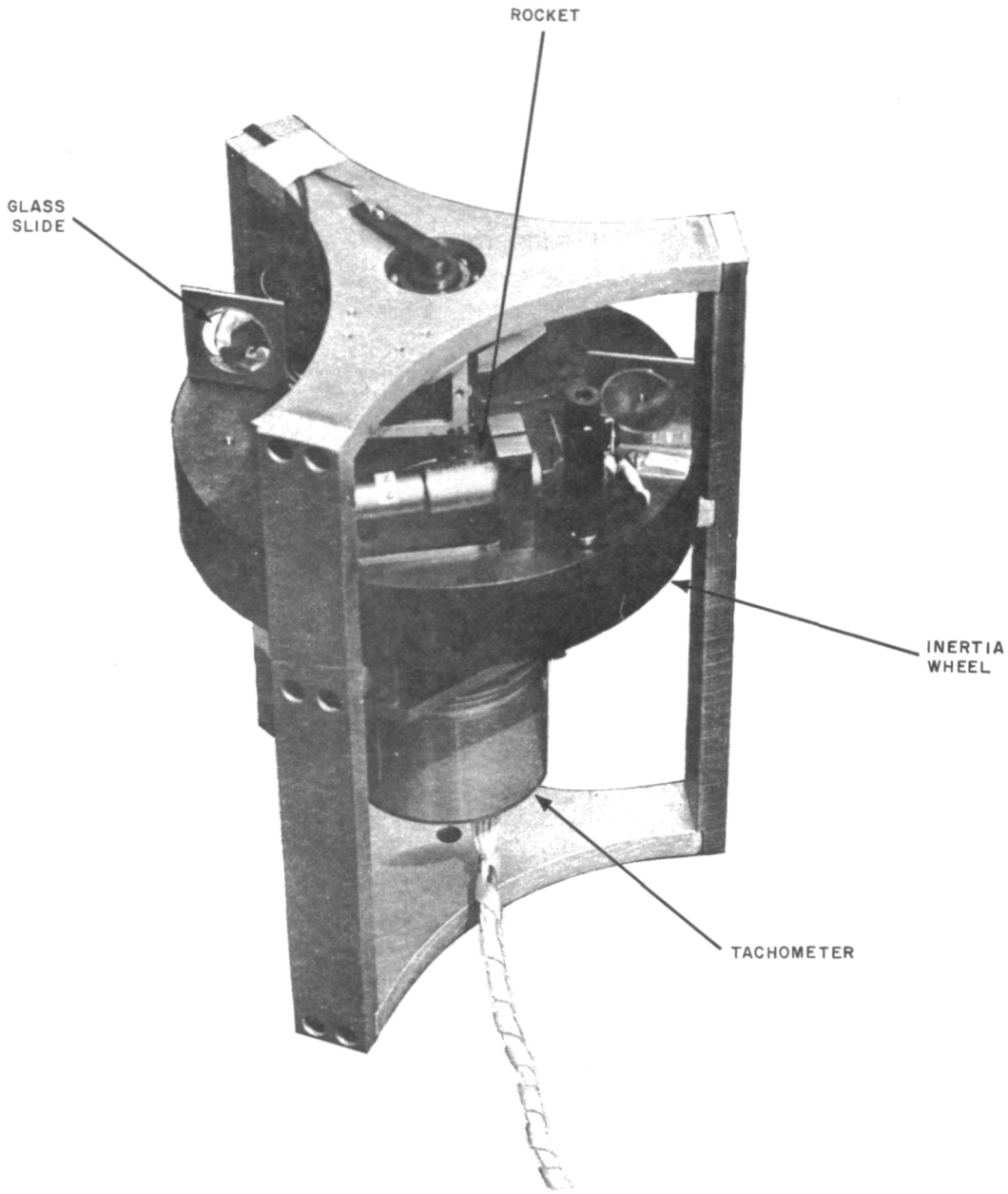


Figure A-1. Inertia Wheel and Accessories Used in Rocket Testing

temperatures and it became necessary to replace it with a magnetic sensing element having an output of 60 pulses per revolution.

3. TEST RESULTS

The sixteen rockets were fired in pairs and all rockets performed successfully with measured impulses near the design value of 2.49 lb.-sec. (for a pair) at atmospheric pressure. Data for the individual rockets are given in Table A-1. The results of the firings are given for the pairs in Table A-2. In the results of the eight firings

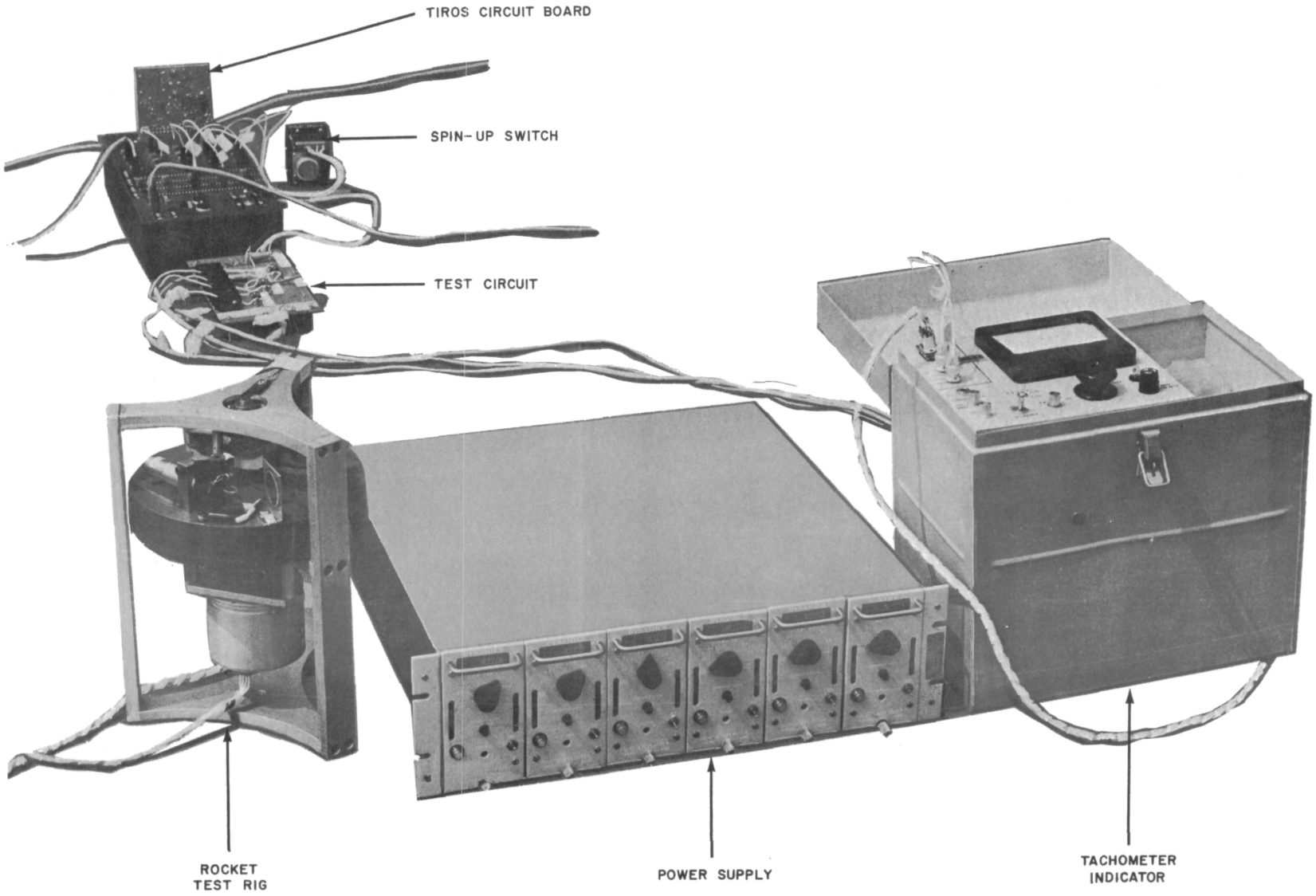


Figure A-2. Equipment Arrangement for Rocket Testing

TABLE A-1. DATA FOR .3KS5 SPIN-ROCKET TESTS

Rocket S/N	Wt. Before Firing (grams)	Wt. After Firing (grams)	Resistance Before Firing (Ohms)	Resistance After Firing (Ohms)	Flight Qualified	Lot No.
1	29.3	25.5	1.0	380K	No	2-2
2	29.3	25.5	1.1	230K	No	2-2
3	29.2	25.5	1.13	>1.0 meg	Yes	2-2
4	29.2	25.5	1.0	27K	Yes	2-2
5	29.6	25.8	1.04	20 meg	Yes	2-2
6	29.3	25.6	1.23	37K	Yes	2-2
7	29.65	25.6	1.08	7 meg	Yes	2-2
8	30.25	26.5	1.16	40K	Yes	2-2
9	28.9	25.15	1.09	165K	Yes	2-2
10	29.55	25.65	1.17	28K	No	2-2
11	29.4	25.65	1.12	7 meg	No	2-2
12	29.4	25.5	1.14	14.5 meg	No	2-2
13	29.6	25.85	1.07	320K	No	2-2
14	30.0	26.35	1.14	1.5 meg	No	2-2
15	31.0	26.85	.88	22 meg	No	2
16	30.75	26.35	1.03	1000 meg	No	2

there was no evidence that resistance mismatch, length of storage, exposure to qualification testing, or rocket temperature at firing had any effect on rocket performance. Examination of the glass slides mounted on the inertia wheel, revealed that the amount of deposition of exhaust products was negligible.

In Table A-2, the weight of mass ejected given in column 4 is the combined change in weight for the two rockets in each pair. It can be seen that rockets (serial Nos.) 15 and 16, which were manufactured in 1959, contained more propellent than the rockets manufactured later, and the pair produced a higher total impulse than the other pairs. Column 5 in Table A-2 lists the maximum increases in angular velocity measured immediately after rocket burnout. The spin impulse, given in column 6 of Table A-2, was calculated from the following equation:

$$I_S = \frac{2\pi J \Delta \omega}{d},$$

TABLE A-2. .3KS5 SPIN-ROCKET REST RESULTS*

Firing Sequence	Rocket S/N	Rocket Temp. Deg. C	Wt. of Mass Ejected ΔM grams	Inertia Wheel $\Delta\omega$ Rev/sec	Spin Impulse I_s lb-sec	Friction Impulse I_f lb-sec	Total Impulse I_t lb-sec	$I_t/\Delta M$ lb-sec per gram
1	1 & 2	+25	7.6	2.31	2.37	0.02	2.39	0.31
2	3 & 4	+25	7.4	2.20	2.24	0.02	2.26	0.31
3	5 & 7	+25	7.85	2.38	2.45	0.02	2.47	0.31
4	11 & 12	+25	7.65	2.21	2.27	0.02	2.29	0.30
5	15 & 16	+25	8.55	2.47	2.54	0.03	2.57	0.30
6	10 & 13	-20	7.45	2.25	2.31	0.02	2.33	0.31
7	6 & 9	-20	7.45	2.22	2.28	0.03	2.31	0.31
8	8 & 14	-20	7.40	2.30	2.36	0.03	2.39	0.32

*Tests were conducted out-of-doors at AED between August 11 and 14, 1964.

where

J is the moment of inertia of the inertia wheel assembly about its spin axis (~ 0.450 lb-in-sec^2),

$\Delta\omega$ is the maximum change in angular velocity of the inertia wheel assembly (revolutions per second), and

d is the distance from the spin axis of the inertia wheel along a perpendicular to the thrust axis of the rocket (2.75 inches).

The friction impulse, column 7 of Table A-2, was calculated as follows:

$$I_f = \frac{2\pi J\alpha t}{d},$$

where

I_f is friction impulse (lb-sec), i.e., the rocket impulse required to overcome the combined forces of friction;

α is the angular deceleration ($d\omega/dt$) of the inertia wheel as the result of the combined friction forces; and

t is the duration of rocket firing (approximately 0.3 second).

The slope of the de-spin curve shown in Figure A-3 furnished the rate of de-spin (angular deceleration) from which the friction impulse was calculated.

The total impulse (I_t), given in column 8, is the algebraic sum of the spin and friction impulses. The nominal value for total impulse of one rocket under vacuum conditions is 1.42, ± 10 percent, pound-seconds. This is equivalent to an impulse of 1.24, ± 10 percent, pound-seconds at atmospheric pressure. For two rockets at atmospheric pressure the nominal impulse is 2.48, ± 10 percent, pound-seconds. The values in column 8 fall within the nominal range for total impulse.

The values in column 9 of Table A-2 give an indication of the efficiency of the rocket propellant. It is seen that the rockets manufactured in 1959 (serial Nos. 15 and 16) consumed more propellant than those of later manufacture and thus, even though they produced the highest total impulse, their efficiency rating was one of the lowest in the test sample. However, this single firing cannot be taken as evidence that aging affected propellant performance.

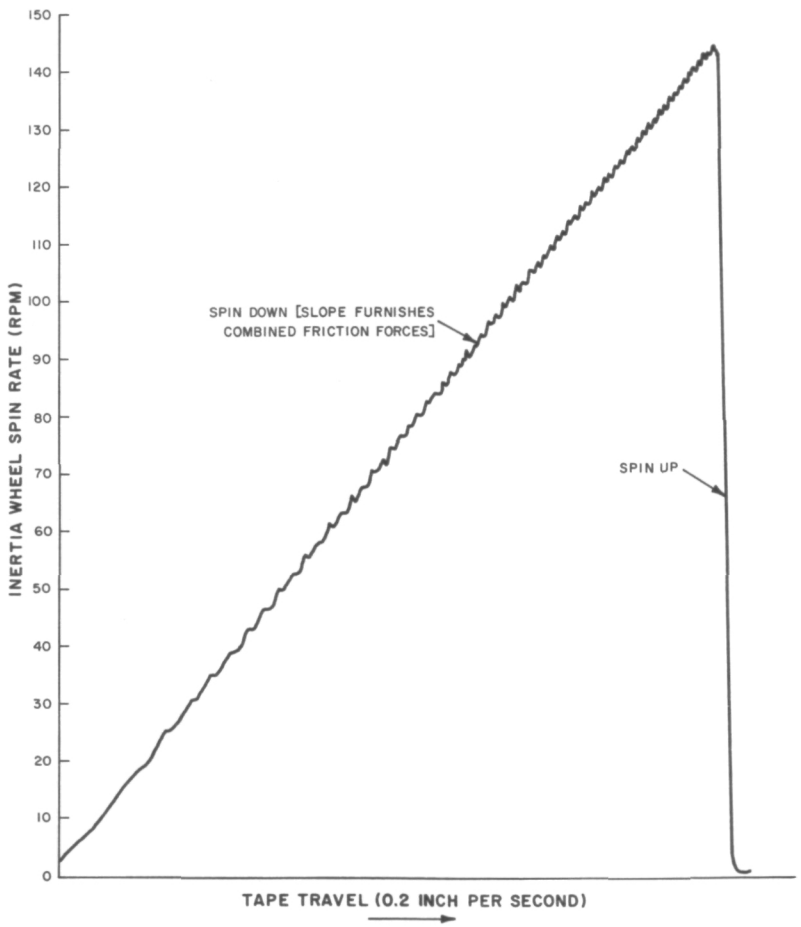


Figure A-3. Rate of De-Spin (Angular Deceleration)

Tmk(s) ®